Pressure Safety Training Objective . . .

To provide the necessary classroom training so that with the required practical experience you will be able to work or design more safely with pressure

Definitions/Concepts

We will discuss:

- ❒ **Force - Area - Pressure**
- ❒ **Pressure - Force devices**
- ❒ **Types/units of pressure and temperature**
- ❒ **P-V-T relationships**

Pressure

Pascal's Law

- Pressure in a contained fluid is transmitted equally in all directions

Pressure is force acting on a given area

$$\boxed{\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{\text{lbs.}}{\text{in}^2}}$$

$$\boxed{\text{Force} = \text{pressure} \times \text{area}}$$

$$= \frac{\text{lbs.}}{\text{in}^2} \times \text{in}^2 = \text{lbs.}$$

An example of pressure, force, and area . . .

Pressure = force per unit area

$$\boxed{\text{Pressure} = \frac{\text{force}}{\text{area}}}$$

A gymnast does handstands . . .

Pressure on one hand

$F_1 = 150$ lbs.

$A_1 = 5\ in^2$

$P_1 = F_1 / A_1$

$P_1 = 150$ lbs. $/ 5\ in^2$

$P_1 = 30$ psi

Pressure on two hands

$F_2 = 150$ lbs.

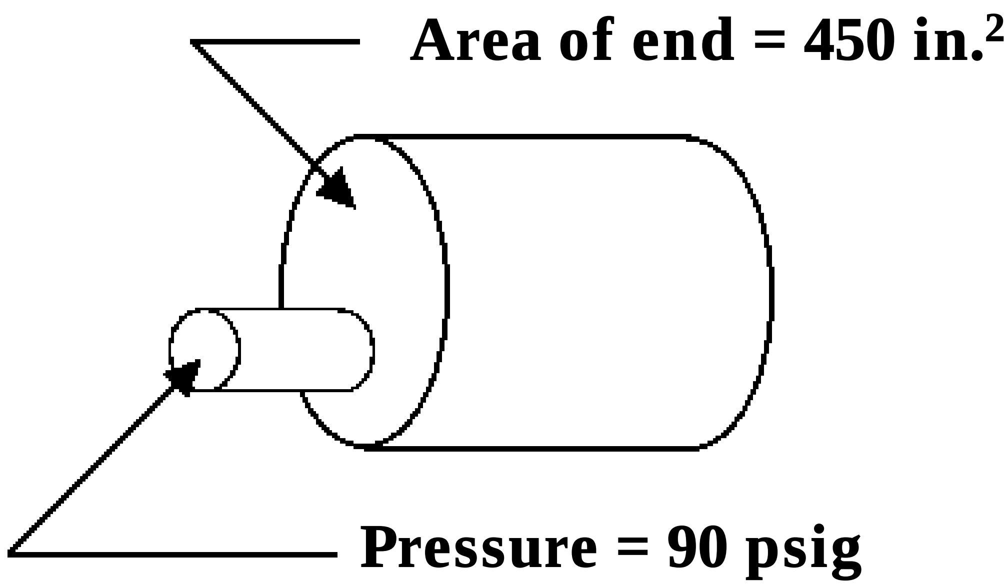
$A_2 = 10\ in^2$

$P_2 = F_2 / A_2$

$P_2 = 150$ lbs. $/ 1\ in^2$

$P_2 = 15$ psi

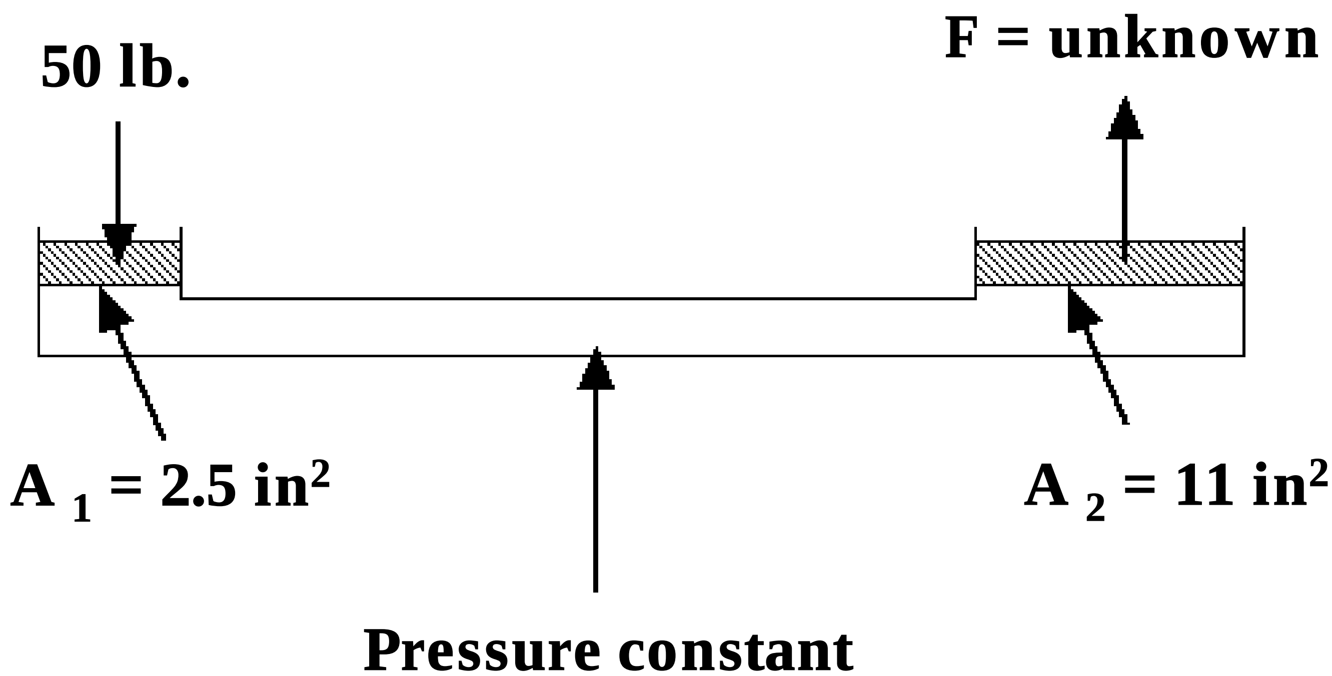
Find the force on the end of the drum shown below:



Solution:

$$P = F / A$$
$$F = P \times A$$
$$= 90\ lb/in^2 \times 450\ in^2$$
$$= 40{,}500\ \text{lbs. of force}$$

Find the upward force exerted on the large piston:



<u>Solution</u>:

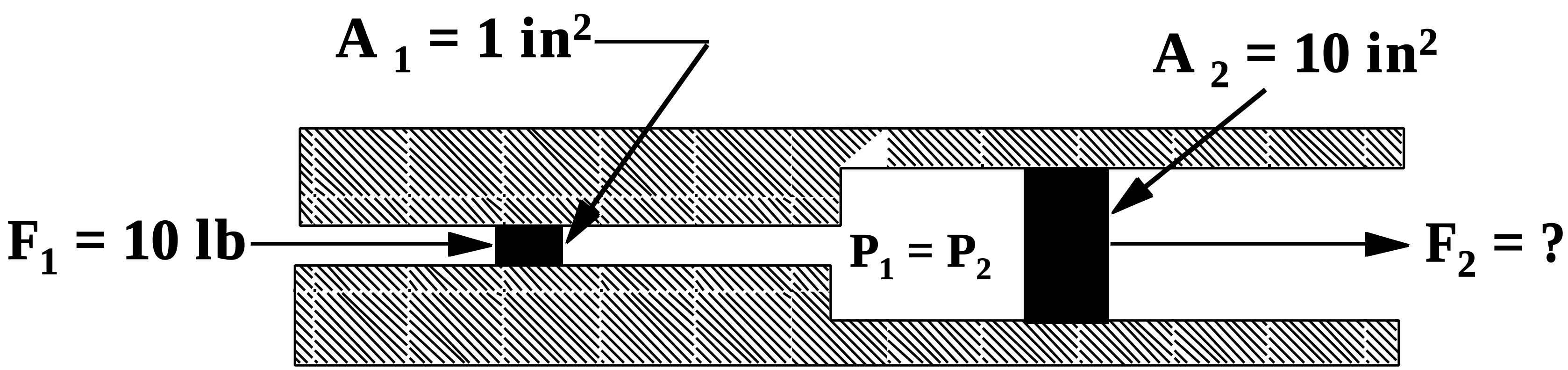
Left side . . .

$$P = F / A_1 = 50\ lb/2.5\ in^2 = 20\ psi$$

Right side . . .

$$F = PA_2 = 20\ psi \times 11\ in^2 = 220\ lbs.$$

Consider this device:

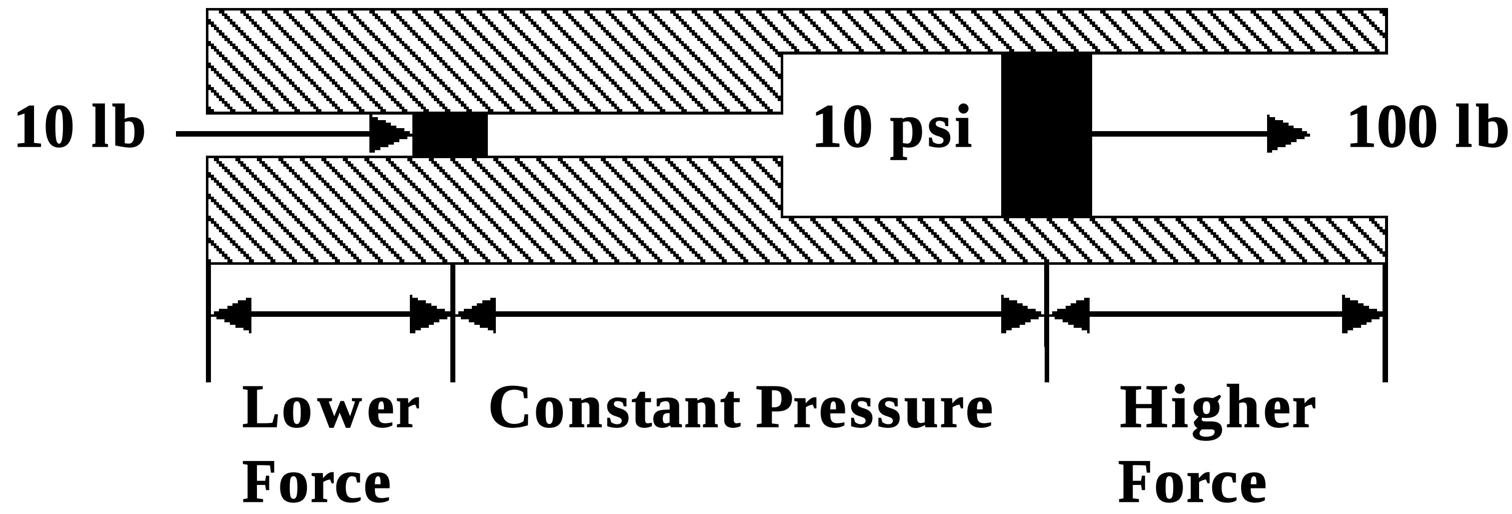


$$P_1 = F_1 / A_1$$
$$= 10\ lb / 1\ in^2 = \underline{10\ psi}$$

$$P_1 = P_2\ \text{(Pascal's Law)}$$

$$F_2 = P_2 \times A_2$$
$$= 10\ psi \times 10\ in^2 = \underline{100\ lbs}$$

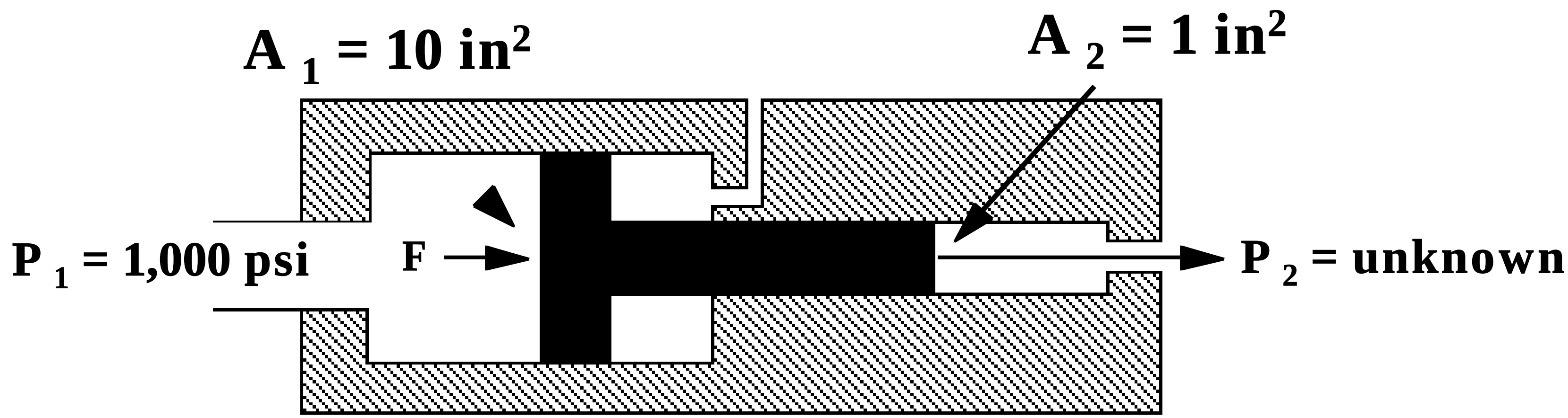
Showing the values determined . . .



Call it –

A force amplifier {Hydraulic jack, Barber's chair, Car lift}

Reverse the device; use a solid piston:



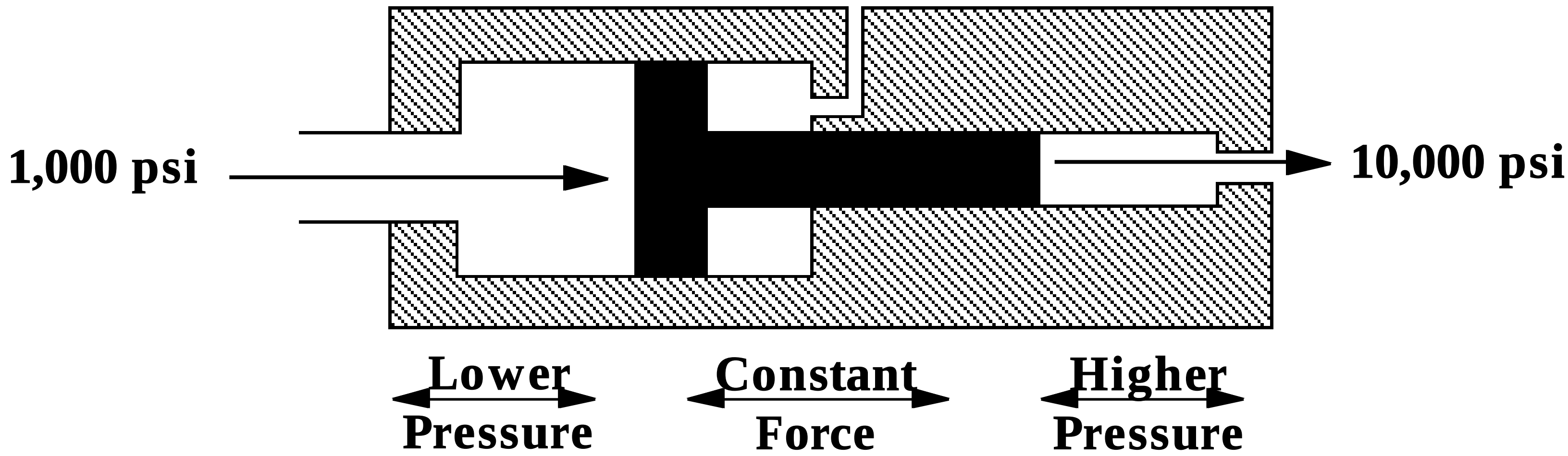
$$F = P_1 A_1$$

$$= 1{,}000 \text{ psi} \times 10 \text{ in}^2 = \underline{10{,}000 \text{ lbs.}}$$

$$P_2 = F / A_2$$

$$= 10{,}000 \text{ lb} / 1 \text{ in}^2 = \underline{10{,}000 \text{ psi}}$$

Showing the values determined . . .



Call it –

A pressure amplifier { **Compressor**
Intensifier

Units of Pressure

(i.e., force per unit area)

Pounds per square inch = psi

1,000 pounds per square inch = 1 ksi

Newtons per square meter = Pascal (Pa)

6,895 Pascals = 1 psi

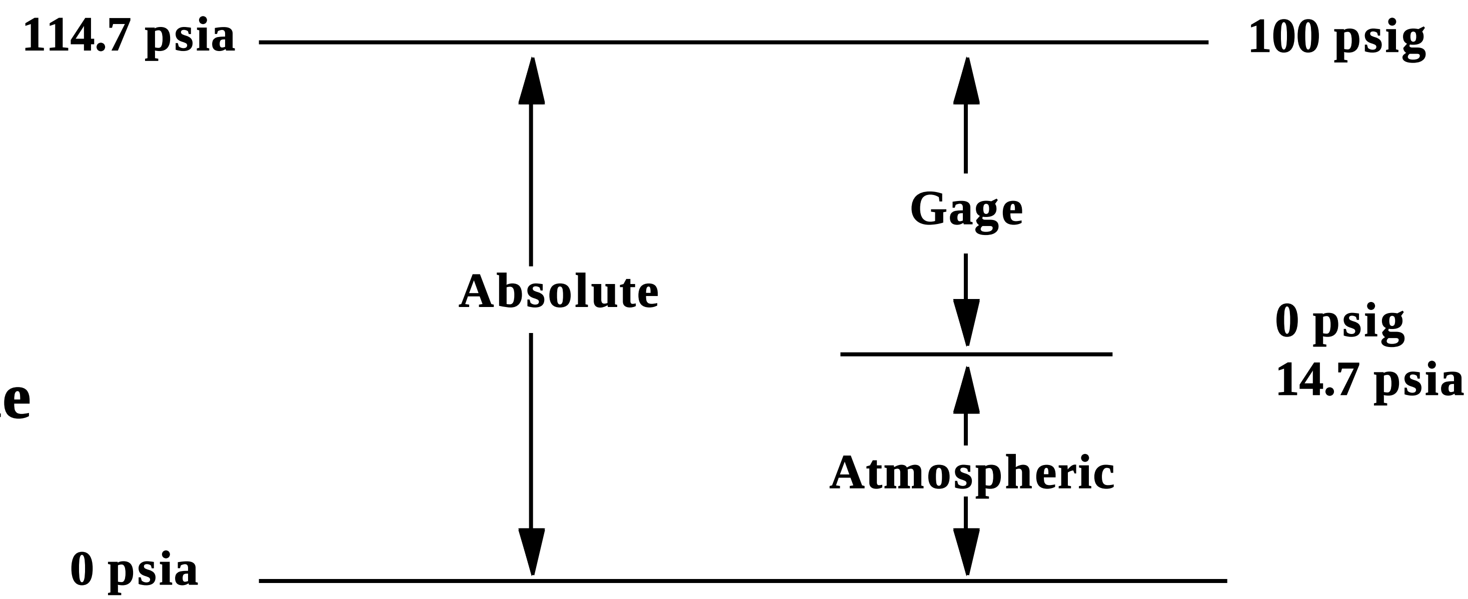
0.000145 psi = 1 Pascal

Kilopascal (kPa): 0.145 psi = 1 kPa

Megapascal (MPa): 145 psi = 1 MPa

Three types of pressure are involved:

- **Atmospheric**
  - 14.7 psia
  - 29.92 in. of mercury (Hg)
  - 407 in. of water (H_2O)
  - 760 torr
  - 1.013 bars
  - 101.4 kPa
- **Gage**
- **Absolute**



Pressure Conversion Chart

multiply no. of (columns) by (cells) To obtain (rows)

To obtain ↓ / multiply no. of →	Atmospheres	Bars	Millibars	In. of Hg (0°C)	In. of H_2O (4°C)	lb/in^2 (psi)	lb/ft^2	ft of H_2O	mm of Hg (Torr)	Microns	Pascals (Newtons/Meter^2)	Kilopascals	Megapascals
Atmospheres		9.869×10^{-1}	9.869×10^{-4}	3.342×10^{-2}	2.458×10^{-3}	6.804×10^{-2}	4.725×10^{-4}	2.9486×10^{-2}	1.3157×10^{-3}	1.3157×10^{-6}	9.863×10^{-6}	9.863×10^{-3}	9.863
Bars	1.013		10^{-3}	3.385×10^{-2}	2.491×10^{-3}	6.895×10^{-2}	4.786×10^{-4}	2.9869×10^{-2}	1.333×10^{-3}	1.333×10^{-6}	10^{-5}	10^{-2}	10
Millibars	1013	1000		33.85	2.491	68.95	4.786×10^{-1}	29.869	1.333	1.333×10^{-3}	10^{-2}	10	1×10^{4}
In. of Hg (0°C)	29.92	29.53	2.953×10^{-2}		7.355×10^{-2}	2.036	1.414×10^{-2}	0.8822	3.937×10^{-2}	3.937×10^{-5}	2.953×10^{-4}	.2953	2.953×10^{2}
In. of H_2O (4°C)	406.8	4.015×10^{2}	0.4015	13.6		27.68	0.1922	11.92	0.5353	5.3533×10^{-4}	4.015×10^{-3}	4.015	4.015×10^{3}
lb/in^2 (psi)	14.696	14.5	1.45×10^{-2}	0.4912	3.613×10^{-2}		6.944×10^{-3}	0.4333	1.934×10^{-2}	1.934×10^{-5}	1.45×10^{-4}	.145	145
lb/ft^2	2116	2.089×10^{3}	2.089	70.73	5.204	144		62.4	2.785	2.785×10^{-3}	2.089×10^{-2}	20.89	2.089×10^{4}
ft of H_2O	33.9	33.456	3.3456×10^{-2}	1.1329	8.33×10^{-2}	2.3076	1.6018×10^{-2}		4.459×10^{-2}	4.459×10^{-5}	33.46×10^{-4}	3.346	3.346×10^{3}
mm of Hg (Torr)	760	750	0.75	25.399	1.868	51.71	0.3591	22.409		10^{-3}	7.502×10^{-3}	7.502	7.502×10^{3}
Microns	760×10^{3}	750×10^{3}	0.75×10^{3}	25.399×10^{3}	1.868×10^{3}	51.71×10^{3}	359.1	22.409×10^{3}	1000		7.502	7.502×10^{3}	7.502×10^{6}
Pascals (Newtons/Meter^2)	1.013×10^{5}	10^{5}	10^{2}	3.386×10^{3}	2.491×10^{2}	6.895×10^{3}	47.88	2986.9	133.3	0.1333		1000	10^{6}
Kilopascals	101.39	100	0.1	3.386	.249	6.897	4.788×10^{-2}	2.987	.1333	1.333×10^{-4}	10^{-3}		1000
Megapascals	.1014	0.1	10^{-4}	3.386×10^{-3}	2.491×10^{-4}	6.897×10^{-3}	4.788×10^{-5}	2.987×10^{-3}	1.333×10^{-4}	1.333×10^{-7}	10^{-6}	10^{-3}	

Volume Conversion Chart

Multiply number of → ; *To obtain* ↓ ; *BY*

To obtain	Cubic Meters	Cubic Centimeters	Liters	Cubic Inches	Cubic Feet	Gallons
Cubic Meters		10^{-6}	10^{-3}	1.639×10^{-5}	0.028	3.785×10^{-3}
Cubic Centimeters	10^{6}		10^{3}	16.39	2.832×10^{4}	3.785×10^{3}
Liters	10^{3}	10^{-3}		0.0164	28.317	3.785
Cubic Inches	6.1×10^{4}	0.061	61.01		1728	231
Cubic Feet	35.31	3.53×10^{-5}	0.035	5.79×10^{-4}		0.134
Gallons	264	2.64×10^{-4}	0.064	4.33×10^{-3}	7.481	

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Conversion Factors

To convert from . . .	And obtain . . .	Multiply by . . .
atm	torr (mmof Hg @ 0°C)	760
atm	psi	1.4500E+01
atm	in. of Hg (@ 0°C)	2.9920E+01
atm	cm. of Hg (@ 0°C)	7.6000E+01
atm	ft. of water (@ 4°C)	3.3900E+01
in. of water (@ 4°C)	atm	2.4580E-03
in. of water (@ 4°C)	in. of Hg	7.3550E-02
in. of water (@ 4°C)	psi	3.6130E-02
in. of water (@ 4°C)	kg/cm^2	2.5400E-03
in. of Hg	torr (mmof Hg @ 0°C)	2.5400E+01
in. of Hg	atm	3.3420E-02
in. of Hg	ft. of water	1.133
in. of Hg	kg/cm^2	3.4530E-02
in. of Hg	psi	4.9120E-01
bars	atm	9.8690E-01
bars	psi	1.4500E+01
bars	dynes/cm^2	1.0000E+06
bars	kg/m^2	1.0200E+04
bars	kpascals	1.0000E+02
pascals	psi	1.4500E-04
pascals	kg/m^2	2.0620E+07
joules	Btu	9.4860E-04
joules	ft-lb	7.3760E-01
watts	joules/s	1
watts	Btu/hr	3.4129
Btu	ft-lb	7.7816E+02
Btu	joules	1.0550E+03
lb TNT	joules	1.9300E+06
lb TNT	ft-lb	1.4200E+06

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Temperature is measured in degrees Fahrenheit or Celsius (°F or °C)

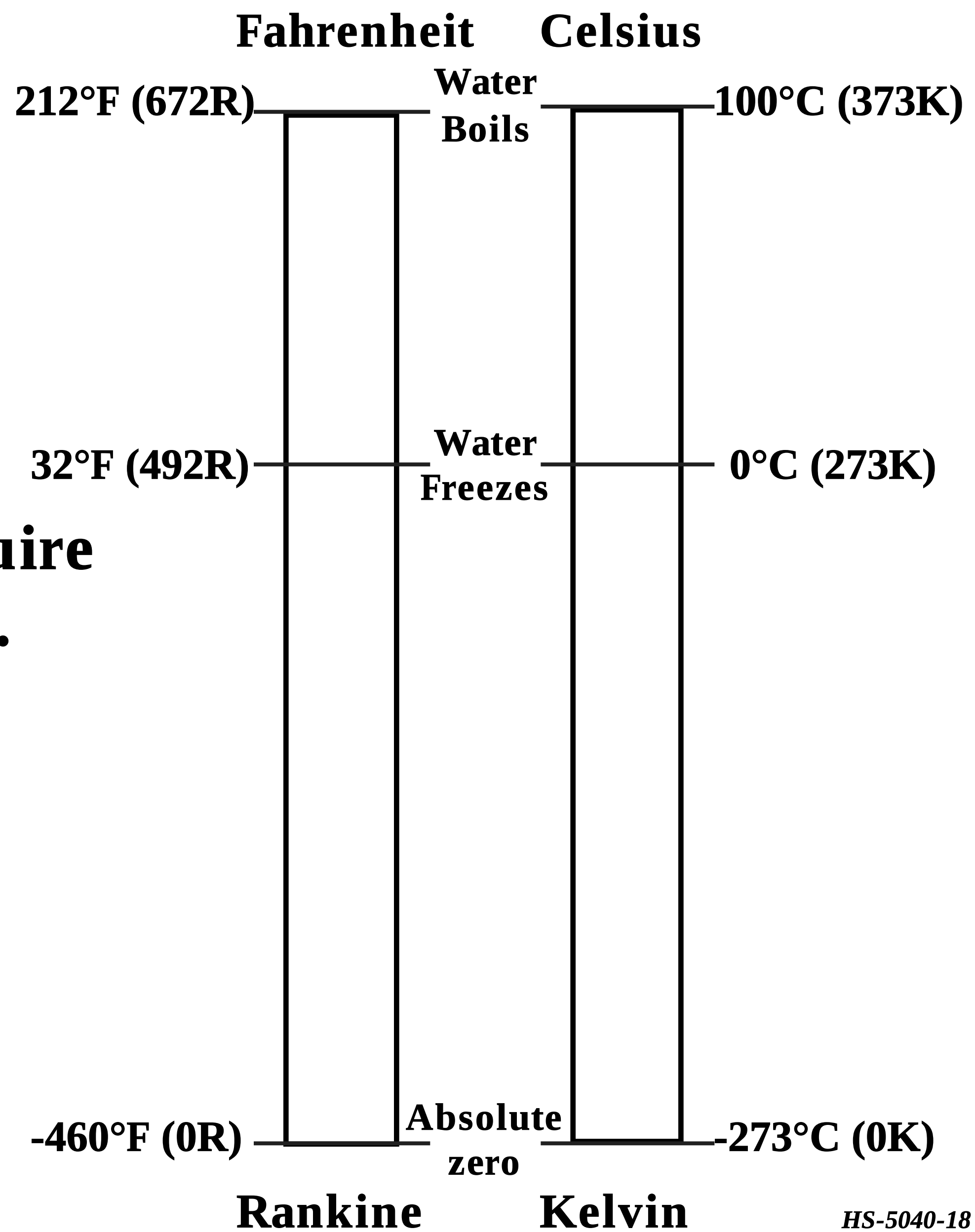
°F = 9 / 5 °C + 32

°C = 5 / 9 (°F - 32)

Note: Fluid calculations require absolute temperatures.

Rankine: R = °F + 460

Kelvin: K = °C + 273



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Fahrenheit to Centigrade

Deg F	0	1	2	3	4	5	6	7	8	9
0	-17.8	-17.2	-16.7	-16.1	-15.6	-15.0	-14.4	-13.9	-13.3	-12.8
10	-12.2	-11.7	-11.1	-10.6	-10.0	-9.4	-8.9	-8.3	-7.8	-7.2
20	-6.7	-6.1	-5.6	-5.0	-4.4	-3.9	-3.3	-2.8	-2.2	-1.7
30	-1.1	-0.6	0.0	0.6	1.1	1.7	2.2	2.8	3.3	3.9
40	4.4	5.0	5.6	6.1	6.7	7.2	7.8	8.3	8.9	9.4
50	10.0	10.6	11.1	11.7	12.2	12.8	13.3	13.9	14.4	15.0
60	15.6	16.1	16.7	17.2	17.8	18.3	18.9	19.4	20.0	20.6
70	21.1	21.7	22.2	22.8	23.3	23.9	24.4	25.0	25.6	26.1
80	26.7	27.2	27.8	28.3	28.9	29.4	30.0	30.6	31.1	31.7
90	32.2	32.8	33.3	33.9	34.4	35.0	35.6	36.1	36.7	37.2
100	37.8	38.3	38.9	39.4	40.0	40.6	41.1	41.7	42.2	42.8
110	43.3	43.9	44.4	45.0	45.6	46.1	46.7	47.2	47.8	48.3
120	48.9	49.4	50.0	50.6	51.1	51.7	52.2	52.8	53.3	53.9
130	54.4	55.0	55.6	56.1	56.7	57.2	57.8	58.3	58.9	59.4
140	60.0	60.6	61.1	61.7	62.2	62.8	63.3	63.9	64.4	65.0
150	65.6	66.1	66.7	67.2	67.8	68.3	68.9	69.4	70.0	70.6
160	71.1	71.7	72.2	72.8	73.3	73.9	74.4	75.0	75.6	76.1
170	76.7	77.2	77.8	78.3	78.9	79.4	80.0	80.6	81.1	81.7
180	82.2	82.8	83.3	83.9	84.4	85.0	85.6	86.1	86.7	87.2
190	87.8	88.3	88.9	89.4	90.0	90.6	91.1	91.7	92.2	92.8
200	93.3	93.9	94.4	95.0	95.6	96.1	96.7	97.2	97.8	98.3
210	98.9	99.4	100.0	100.6	101.1	101.7	102.2	102.8	103.3	103.9
220	104.4	105.0	105.6	106.1	106.7	107.2	107.8	108.3	108.9	109.4
230	110.0	110.6	111.1	111.7	112.2	112.8	113.3	113.9	114.4	115.0
240	115.6	116.1	116.7	117.2	117.8	118.3	118.9	119.4	120.0	120.6
250	121.1	121.7	122.2	122.8	123.3	123.9	124.4	125.0	125.6	126.1

Deg F	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Deg C	0.0	0.06	0.11	0.17	0.22	0.28	0.33	0.39	0.44	0.50

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Centigrade to Fahrenheit

Deg F	0	1	2	3	4	5	6	7	8	9
0	32.0	33.8	35.6	37.4	39.2	41.0	42.8	44.6	46.4	48.2
10	50.0	51.8	53.6	55.4	57.2	59.0	60.8	62.6	64.4	66.2
20	68.0	69.8	71.6	73.4	75.2	77.0	78.8	80.6	82.4	84.2
30	86.0	87.8	89.6	91.4	93.2	95.0	96.8	98.6	100.4	102.2
40	104.0	105.8	107.6	109.4	111.2	113.0	114.8	116.6	118.4	120.2
50	122.0	123.8	125.6	127.4	129.2	131.0	132.8	134.6	136.4	138.2
60	140.0	141.8	143.6	145.4	147.2	149.0	150.8	152.6	154.4	156.2
70	158.0	159.8	161.6	163.4	165.2	167.0	168.8	170.6	172.4	174.2
80	176.0	177.8	179.6	181.4	183.2	185.0	186.8	188.6	190.4	192.2
90	194.0	195.8	197.6	199.4	201.2	203.0	204.8	206.6	208.4	210.2
100	212.0	213.8	215.6	217.4	219.2	221.0	222.8	224.6	226.4	228.2
110	230.0	231.8	233.6	235.4	237.2	239.0	240.8	242.6	244.4	246.2
120	248.0	249.8	251.6	253.4	255.2	257.0	258.8	260.6	262.4	264.2
130	266.0	267.8	269.6	271.4	273.2	275.0	276.8	278.6	280.4	282.2
140	284.0	285.8	287.6	289.4	291.2	293.0	294.8	296.6	298.4	300.2
150	302.0	303.8	305.6	307.4	309.2	311.0	312.8	314.6	316.4	318.2
160	320.0	321.8	323.6	325.4	327.2	329.0	330.8	332.6	334.4	336.2
170	338.0	339.8	341.6	343.4	345.2	347.0	348.8	350.6	352.4	354.2
180	356.0	357.8	359.6	361.4	363.2	365.0	366.8	368.6	370.4	372.2
190	374.0	375.8	377.6	379.4	381.2	383.0	384.8	386.6	388.4	390.2
200	392.0	393.8	395.6	397.4	399.2	401.0	402.8	404.6	406.4	408.2
210	410.0	411.8	413.6	415.4	417.2	419.0	420.8	422.6	424.4	426.2
220	428.0	429.8	431.6	433.4	435.2	437.0	438.8	440.6	442.4	444.2
230	446.0	447.8	449.6	451.4	453.2	455.0	456.8	458.6	460.4	462.2
240	464.0	465.8	467.6	469.4	471.2	473.0	474.8	476.6	478.4	480.2
250	482.0	483.8	485.6	487.4	489.2	491.0	492.8	494.6	496.4	498.2
Deg C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Deg F	0.0	0.18	0.36	0.54	0.72	0.9	1.08	1.26	1.44	1.62

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Three parameters describe the state of a fluid

Pressure

Volume — Cubic centimeters (cc or cm^3), Liters (l), Cubic inches (in^3), Cubic feet (ft^3)

Temperature

P V T data define the fluid's "equation of state" (EOS)

Given any two parameters, the third may be determined.

There are differences between the two types of fluids:

Liquid

- **Obeys Pascal's Law**
- **Volume = f(T,P)**
- **Seeks own level and has a free surface**
- **Relatively incompressible***

Gas

- **Obeys Pascal's Law**
- **Volume = f(T,P)**
- **Fills any container, regardless of shape**
- **Compressible***

*** *Most important for stored energy considerations. For water, volume reduction is ~1/3% for every 1,000 psi pressure. For helium, volume reduction depends on the pressure range; i.e., 30% from 2 ksi to 3 ksi, 10% from 7 ksi to 8 ksi.***

Summary Points

- **Pressure is force per unit area: P = F / A**

- **Force amplifiers use a constant pressure to multiply forces.**

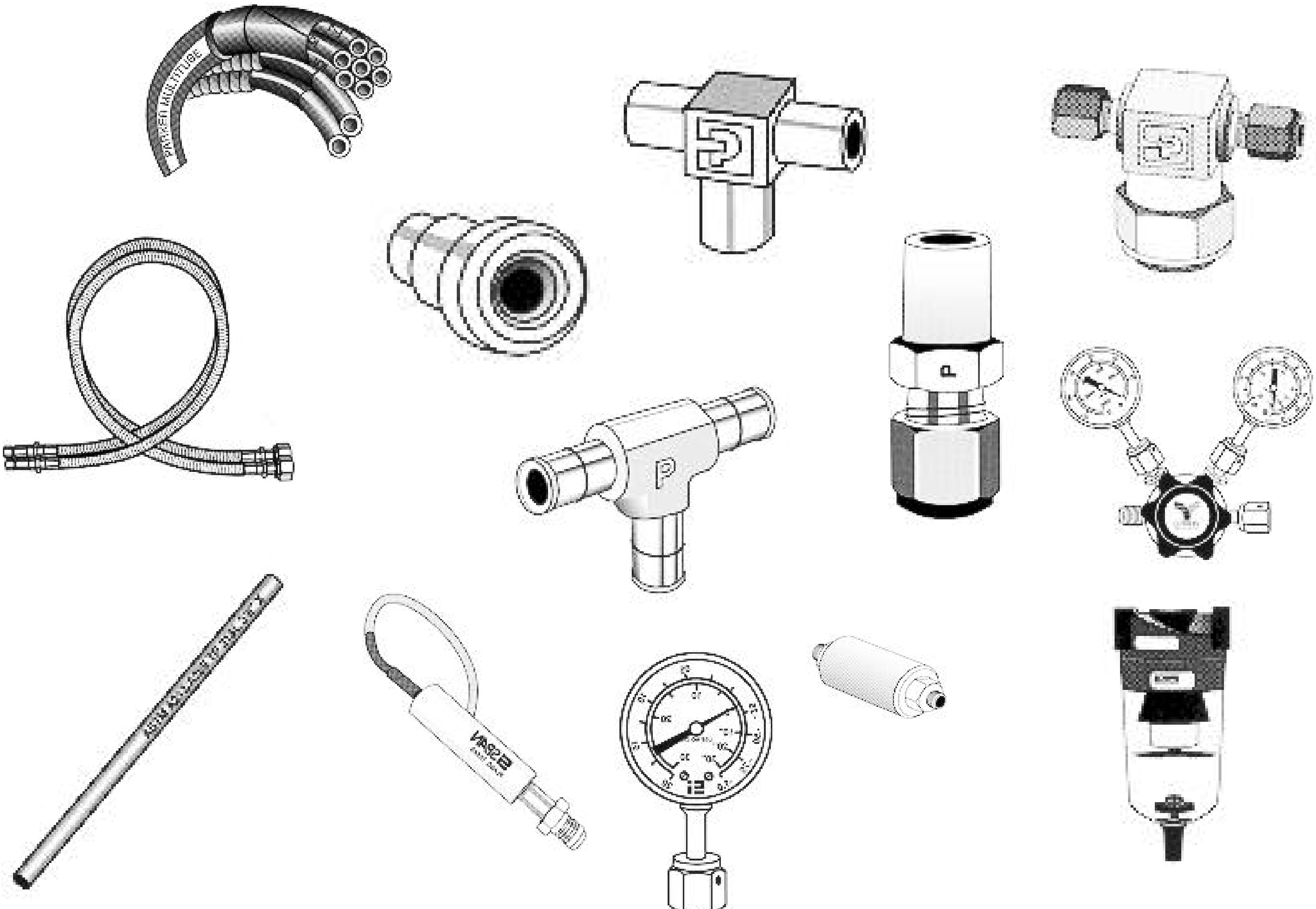
- **Pressure amplifiers use a constant force to multiply pressures.**

- **Pressure is usually measured in psi, and sometimes in Pascals.**

Summary Points (continued)

- Absolute pressure is the sum of atmospheric and gage pressure.
- Fluid calculations require absolute temperatures and absolute pressures.
- Pressure, volume, and temperature define the state of a fluid.
- Gases are highly compressible.
- Liquids are not very compressible.

Intermediate Fittings and Equipment



Intermediate Fittings and Equipment

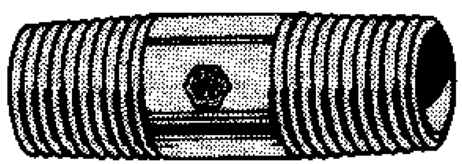
We will discuss:

- ❒ **Types of fittings/equipment**
- ❒ **How to determine component M.A.W.P.**
- ❒ **Considerations for fitting selection**
- ❒ **Types of valves and specialty hardware**

(Reference Appendix D, "Hardware and Equipment," in the DOE Pressure Safety Guidelines Manual.)

<u>National pipe taper thread (NPT)</u>

- **Interference fit. Must use sealant/lubricant to seal.**
- **Generally <u>not a good choice</u> for assembly/reassembly.**
- **Assume M.A.W.P. of 125 psi (brass) and 150 psi (steel) unless otherwise referenced.**
- **Sample M.A.W.P. calculation based on ANSI B31.1.**



(Reference Appendix D, page D-3)

Symbols for stress can be stressful!

$$SE = \text{Allowable Stress} = \frac{\text{Tensile or Ultimate Stress}}{\text{Safety Factor}}$$

For example:

Ultimate Stress = 60,000 psi
Safety Factor = 4

$$SE = \frac{60{,}000}{4} = 15{,}000 \text{ psi}$$

Difference between pipe and tube

- **Pipe sizes are based on fixed outside diameter and a nominal inside diameter which varies with schedule number.**
- **IPS refers to nominal pipe size.**
- **Pressure rating is determined by schedule.***

IPS	SCH	O.D.	I.D.	M.A.W.P.
1”	40	1.315”	1.049”	1,350 psi
1”	80	1.315”	.957”	1,800 psi
1”	160	1.315”	.815”	2,530 psi

(Reference Industrial Fluid Power Text, Volume 1)

**Example only*

Difference between pipe and tube (continued)

- **Tube sizes are based on an exact outside diameter and wall thickness.**
- **Pressure rating is determined by wall thickness.**

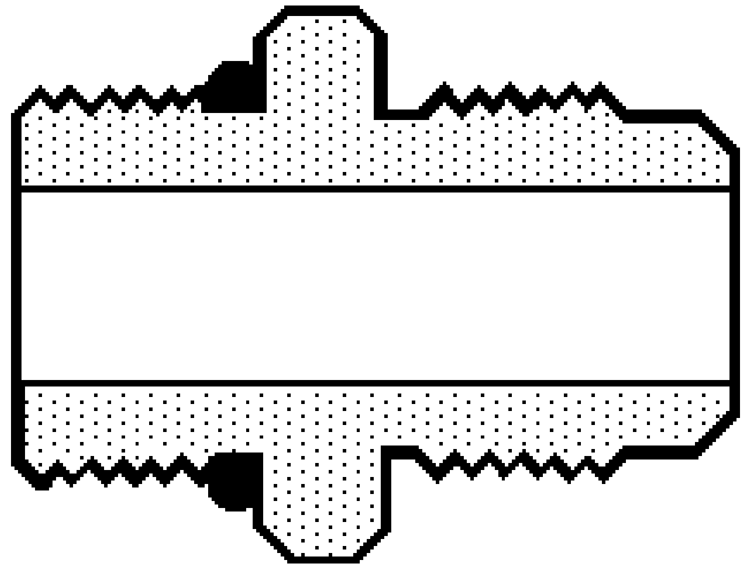
Tube Size	O.D.	Wall Thickness	M.A.W.P.
1/4”	.250”	.020”	2,700 psi
1/4”	.250”	.035”	4,930 psi
1/4”	.250”	.049”	7,150 psi

(Reference Appendix D, page D-16; 304 SST tubing per ASTM A-269, Table D-20.)

M.A.W.P. also depends on the pipe or tube size

- **1/4” SCH 40 black steel pipe (threaded) = 1,920 psi M.A.W.P.**
- **1” SCH 40 black steel pipe (threaded) = 1,080 psi M.A.W.P. (Reference Appendix D, page D-7, table D-6)**
- **1/4” x .020 wall SST tube = 2,700 psi M.A.W.P.**
- **3/8” x .020 wall SST tube = 1,760 psi M.A.W.P. (Reference Appendix D, page D-16, ASTM-A269, table D-20)**

Straight Thread Fittings
(Face Seal Fittings)



Not to be confused with NPT.

Requires sealing device.

Useful for both vacuum and pressure.

Well suited to quick make-up connections.

(Reference Appendix D, page D-19)

Straight Thread Fittings (continued)

Examples:

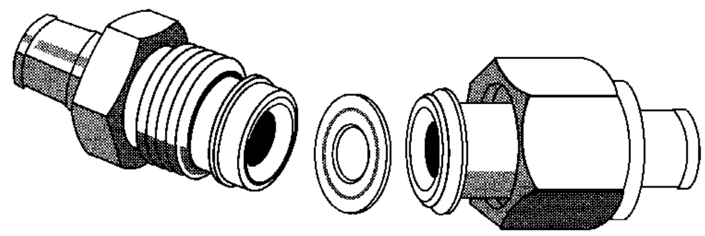
RL (Rad Lab): Uses a flat rubber gasket. Mainly vacuum use. Rated to 125 psi maximum.

VCO (Vacuum Coupling O-ring): Uses an o-ring. Rated to 2,400 psi and above (temperature dependent).*

VCR (Vacuum Coupling Rad Lab): Uses a metal gasket. Rated to 2,400 psi and above.*

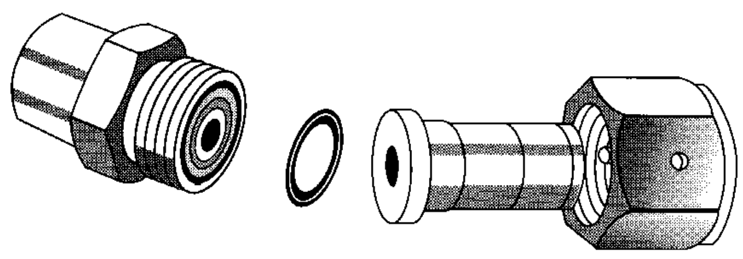
**** Refer to manufacturer's catalog***

(Reference Appendix D, page D-19)



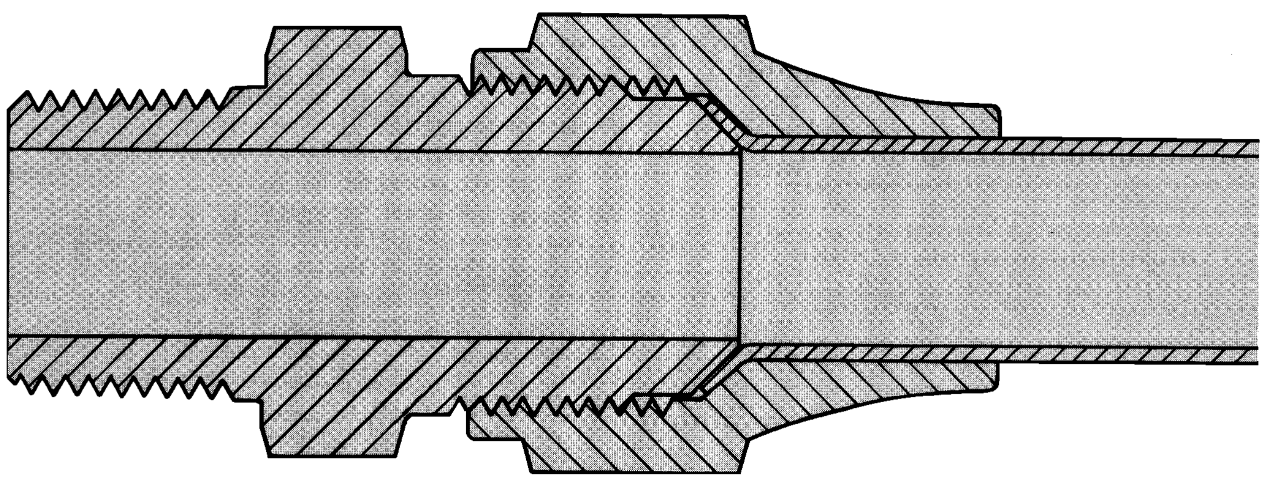
<u>Remember</u>:

- **The threads carry the load.**
- **The gasket or sealant make the liquid or gas tight seal.**



Flare Fittings

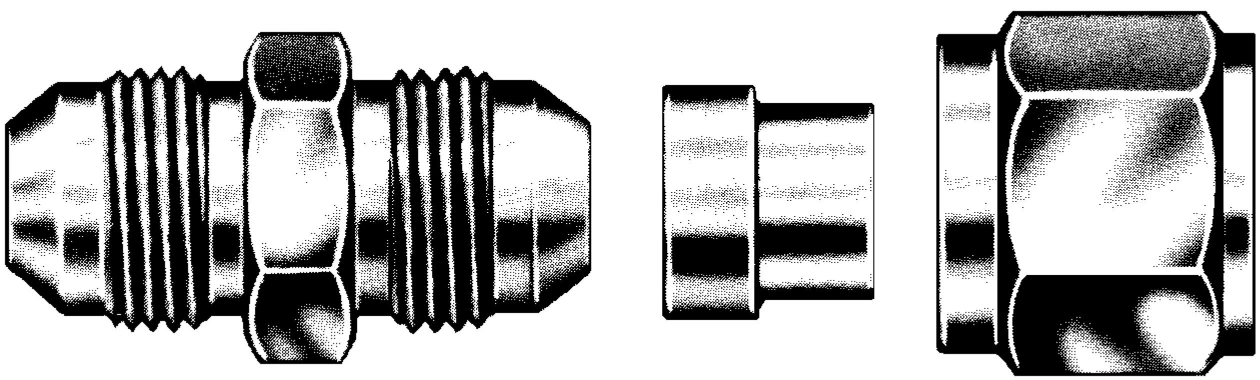
- **45° Two Piece**
  - **Tube end flared to seal on mating part.**
  - **Primarily brass construction.**
  - **Common in refrigeration.**



(Reference Appendix D, page D-19)

Flare Fittings (continued)

- **37° Three Piece (Parker Triple Lok)**
  - **Common in automotive.**
  - **Refer to Appendix D, page D-20 for tubing minimum/ maximum wall thickness.**



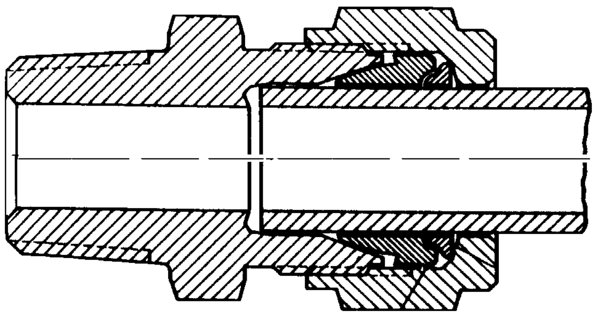
For both 45° and 37° flare fittings, M.A.W.P. is determined by tube dimensions.

Compression Tube Fittings

(Flareless or Bite-Type)

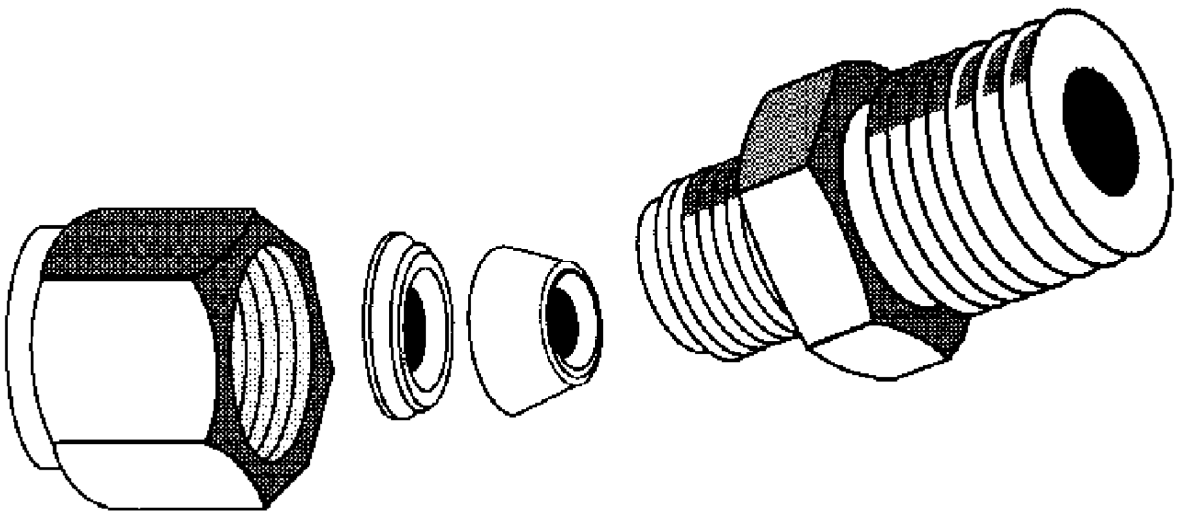
- **Pressure seal achieved by a ferrule system that either bites or deforms tube O.D.**
- **Simple make-up and assembly.**
- **Consider minimum/maximum tube wall thickness (refer to Appendix D, page D-20).**
- **Consider tubing hardness.**

Bite-Type Flareless Tube Fitting



Compression Tube Fittings (continued)

DON'T INTERCHANGE DIFFERENT MANUFACTURER'S COMPONENTS.



Ratings based on tube M.A.W.P. unless fitting includes weaker element; i.e., pipe threads.

Determining component M.A.W.P.

- **DOE Pressure Safety Guidelines Manual (Appendix D, page D-19).**
- **M.A.W.P. rating is stamped on the part.**
- **Engineering Standard Reference (ESR-LLNL only).**
- **Manufacturer's catalog/data sheets.**
- **Lot sample pressure testing.**

Temperature Considerations

- Consider strength of soldered or welded joints (refer to Appendix D, page D-24).
- Components are usually pressure rated at 70°F (21°C).
- M.A.W.P. is based on operating temperature.

Ensure System is Compatible With Fluid

❒ **Consider**

- **fittings**
- **seals**
- **lubricants**

Reference charts (Appendix A)

Valves

USED TO CONTROL THE FLOW OF FLUIDS

- **Many types and manufacturers available.**
- **Applications frequently overlap.**
- **Before selection, define requirements and match according to manufacturer recommendations.**

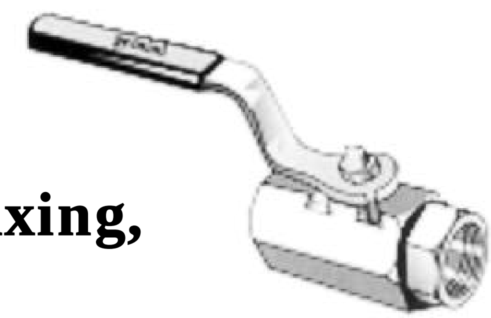
Selection of a valve requires consideration of:

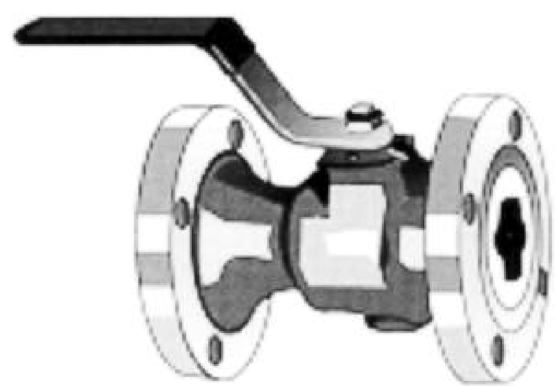
- Operating pressure/temperature
- Flow requirement/C_v
- Body material/stem packing vs. fluid
- End connection type and size
- Flow pattern
- Flow control - shut off, regulating, metering

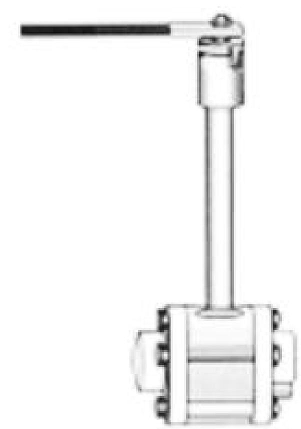
Valve Types

BALL VALVES

- **Full flow, 1/4 turn operation, non-directional**
- **Use only wide open or fully closed**
- **Low cost, simple construction**
- **Used for on/off service, fluid mixing, switching manifolds**





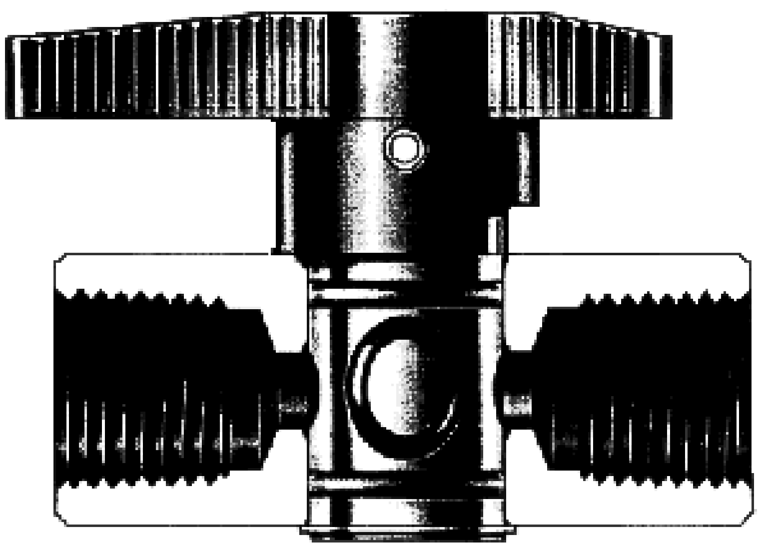


Valve Types (continued)

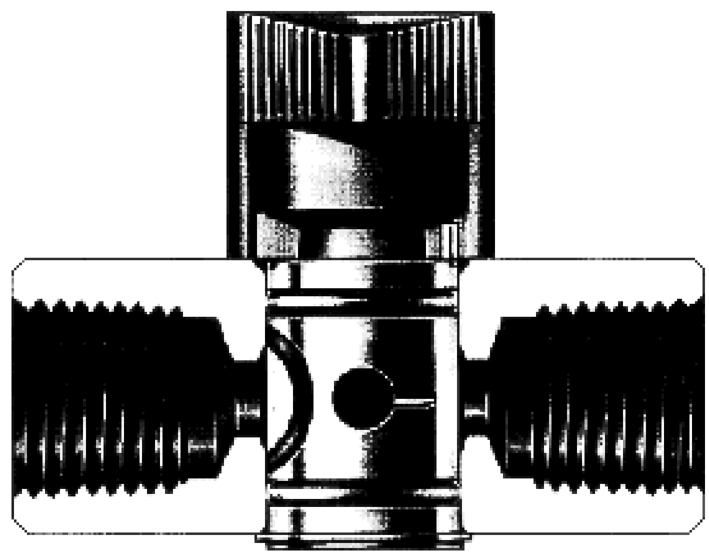
PLUG VALVES

- High capacity, 1/4 turn operation, directional
- Moderate vacuum service
- Flow throttling with interim positioning
- Simple construction, o-ring seal

Open



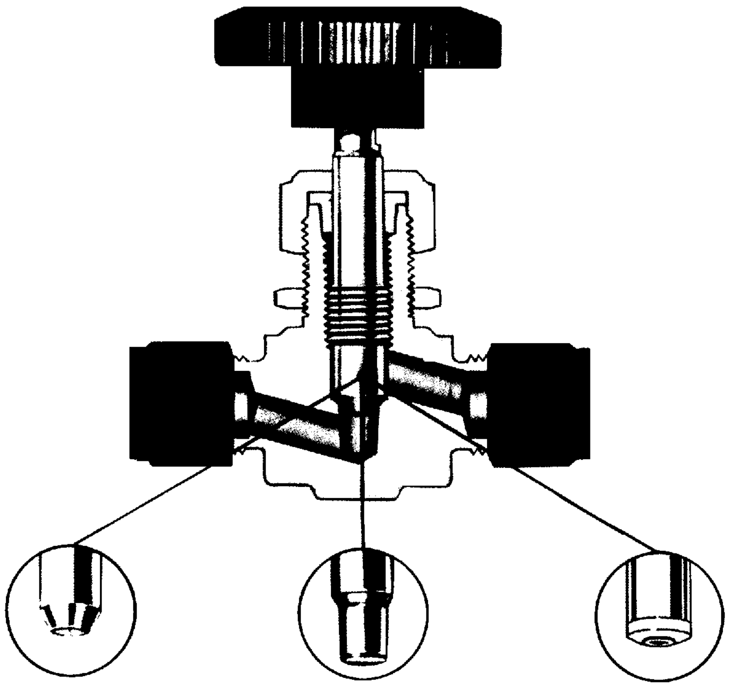
Closed



Valve Types (continued)

REGULATING (Needle) VALVES

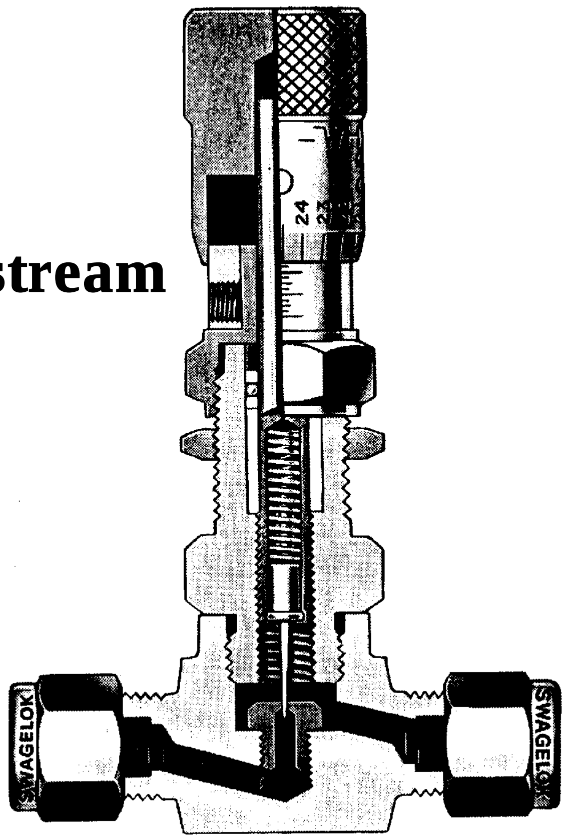
- Refers to small valve where stem is needle-like with point fitting into orifice
- Used for throttling and shut-off on instrumentation lines, test stands, etc.
- Different stem tips available



Valve Types (continued)

METERING VALVES

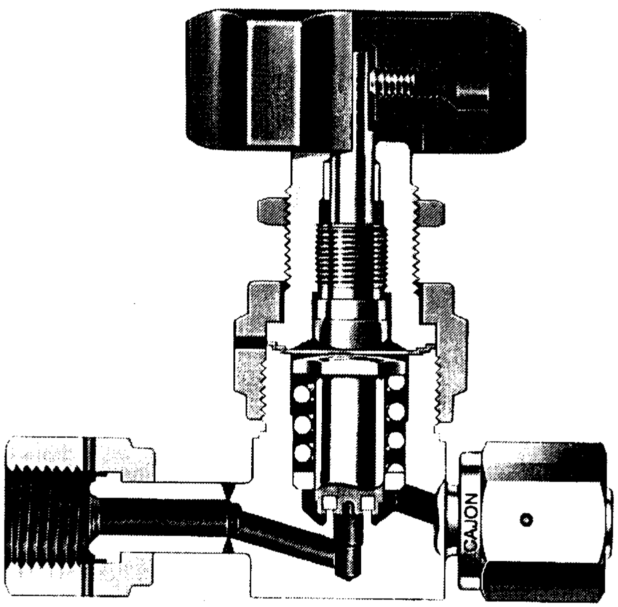
- Precise control of liquid and gas in critical applications
- Similar to needle type, but with smaller orifice and gradually contoured stem points
- Fluids need to be filtered
- Usually requires a shut-off valve upstream



Valve Types (continued)

DIAPHRAGM VALVES

- **Packless, hermetically sealed**
- **Soft stem tip**
- **Frequently higher pressure rating than bellows valve**

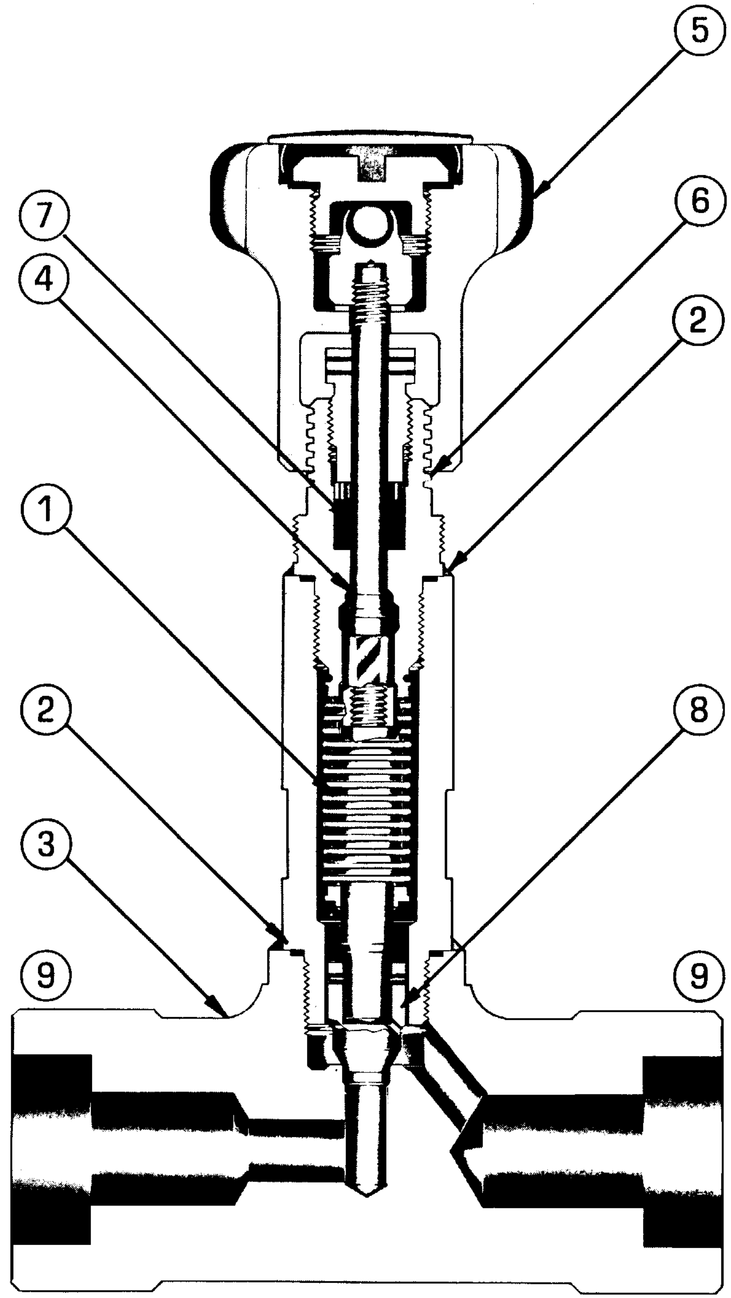


Valve Types (continued)

BELLOWS VALVES

- Packless, hermetically sealed
- Bellows may be welded for leak tight service
- Ideal for use with ultra-high vacuum, cryogenics, toxic, corrosive and radioactive fluids
- Suited for high temperature

1) Packless long life bellows construction
2) All welded construction
3) Forged body to SA182-316 or SA105-C5
4) Back seating
5) Manual or pneumatic operation
6) Long life lubricated ACME power threads provide low operating torque & tight shut-off
7) Secondary packing
8) 17-4PH hardened plug or stellited seat & plug
9) Socket weld connections in 3/4” or 1” body sizes



HS-5040-49

High Purity Regulators

USED TO PREVENT CONTAMINATION OF HIGH PURITY SYSTEMS AND TO PROVIDE REGULATION OF CORROSIVE AND TOXIC GASES

❒ **Applications include:**

- **Gas chromatography**
- **Semiconductor manufacturing**
- **Crystal growing**

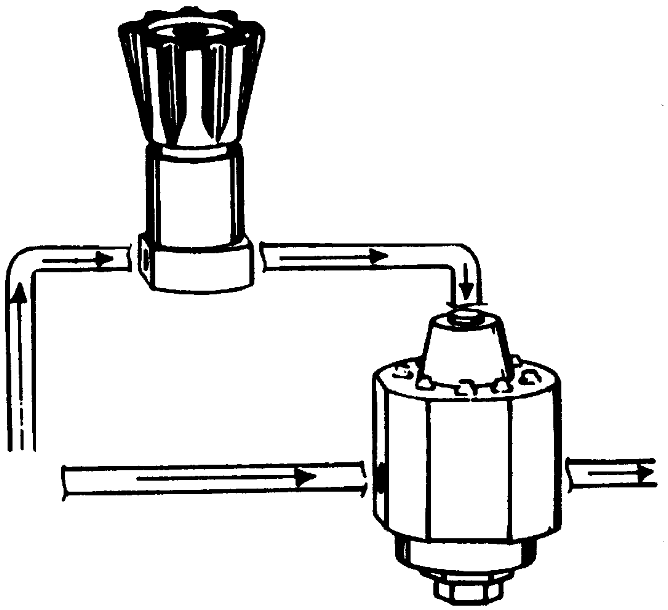
High Purity Regulators (continued)

❐ **Design features:**

- **Wetted parts commonly SST, Kel-F and Teflon**
- **Minimum internal frictional contact and unswept internal volume**
- **Electropolished internal surface finishes**
- **Tied diaphragm attached to poppet valve**
- **Clean room assembly and testing**

Dome Loaded Regulators

- Adjusts delivery pressure remotely (i.e., toxic gases)
- High flow rates, constant delivery pressure
- Can be used with either gases or liquids
- Rated inlet to 10,000 psi for SST models



Specialty Equipment

❒ **Toxic gas bottle buggy:**

- **Safely contains a leaking cylinder**

❒ **Toxic gas negative air enclosure:**

- **Vents any leaking gas through a scrubber away from personnel**

Specialty Equipment (continued)

❒ **Pressure transducers:**

- **Pressure to electrical analog readout**
- **Signal used for monitoring or control**
- **Remote applications**

❒ **Safety regulator manifold:**

- **Reduces cylinder pressure for system/experiment**
- **Regulator and system are protected with relief devices**

Pressure Testing

- ❐ **Why do we pressure test?**
  1. **Safety**
  2. **Reliability**
  3. **Ensure leak tightness**
- ❐ **Requirements for pressure testing:**
  1. **Engineering Safety Note/test procedure**
  2. **Proof/leak test requirements**
  3. **<u>ALWAYS conducted remotely</u>**
- ❐ **Labeling:**
  1. **Identification**
  2. **Tracking**
- ❐ **Why retest or reinspect?**
  1. **Safety**
  2. **Maintenance**
  3. **Reliability**

Requirements for Pressure Testing

Vessels or systems that require an Engineering Safety Note
(see Documentation Guide)

1. **Engineering Safety Note (signed by:)**
   Responsible Individual
   Pressure Consultant
   Division Leader
   Deputy Associate Director for M. E. (DAD)*

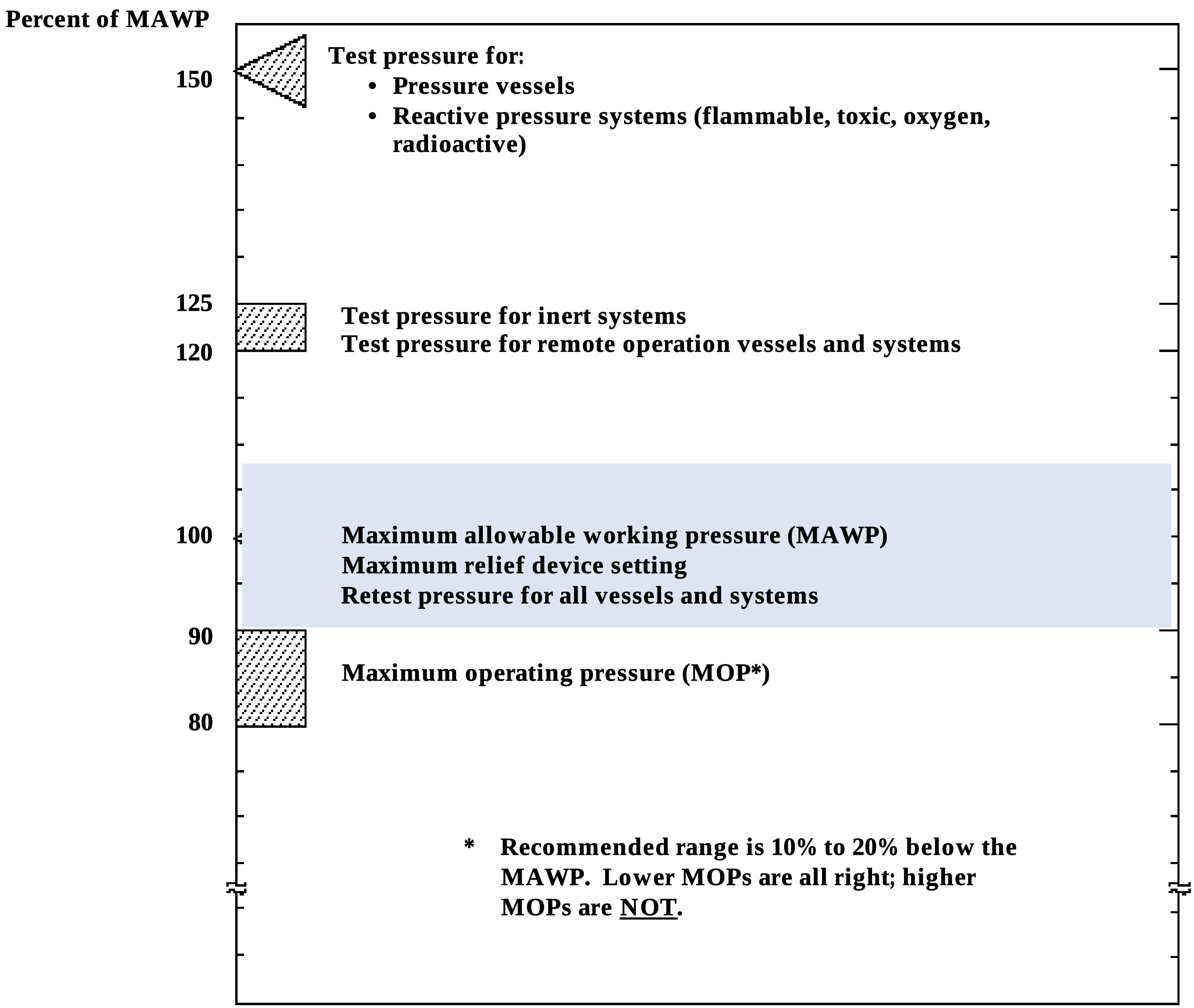
2. **Pressure Test Procedure:**
   (Included in the Safety Note, or must be written by the Responsible Designer, and signed by the Pressure Consultant)

3. **Fill out Building 343 Test Request:**
   Contract with this facility to do the testing at Building 343 or in place.

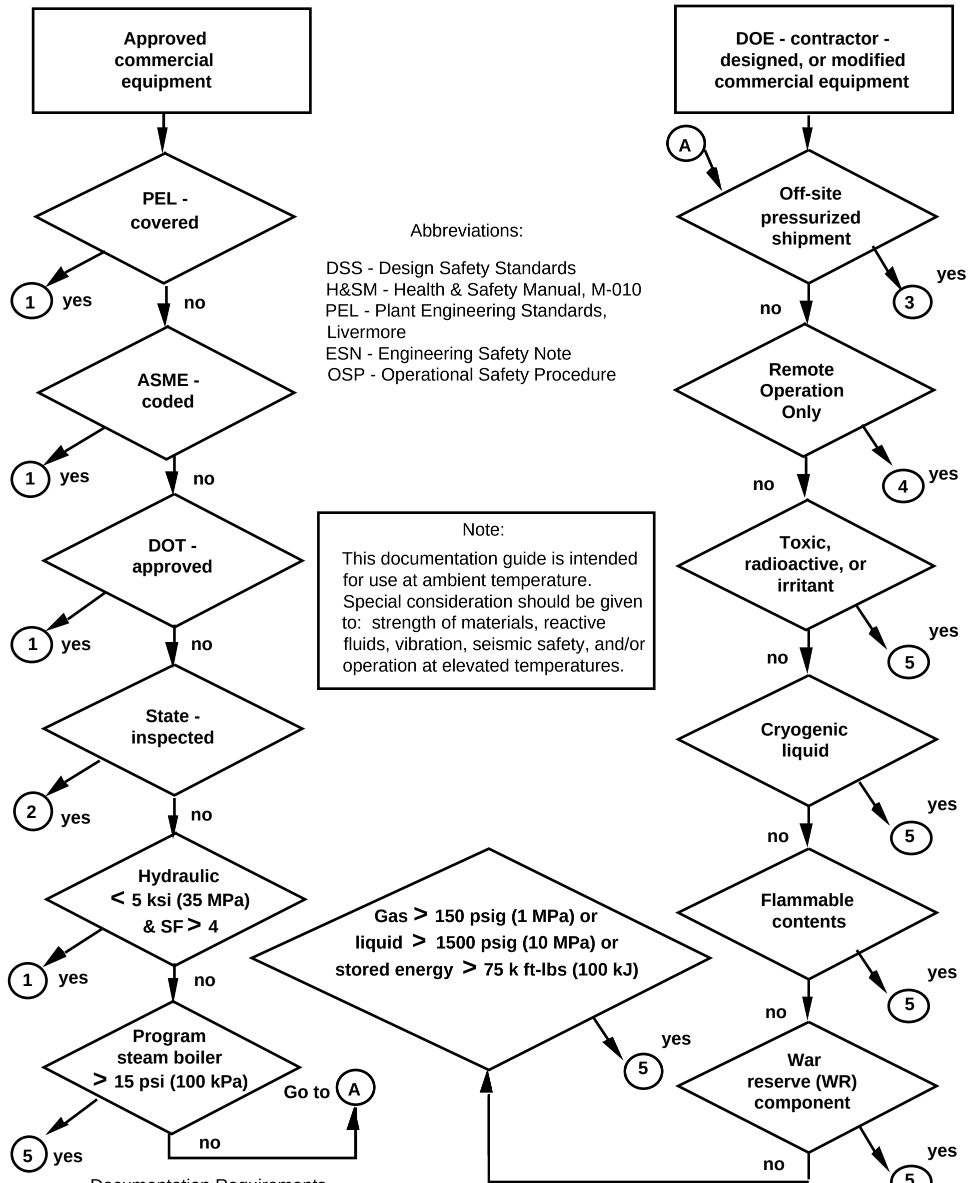
LLNL Example

Brittle materials or Safety Factor of less than 3

Relationships of defined pressure terms



LLNL Documentation Guide for Pressure Equipment



Abbreviations:

DSS - Design Safety Standards
H&SM - Health & Safety Manual, M-010
PEL - Plant Engineering Standards, Livermore
ESN - Engineering Safety Note
OSP - Operational Safety Procedure

Note:

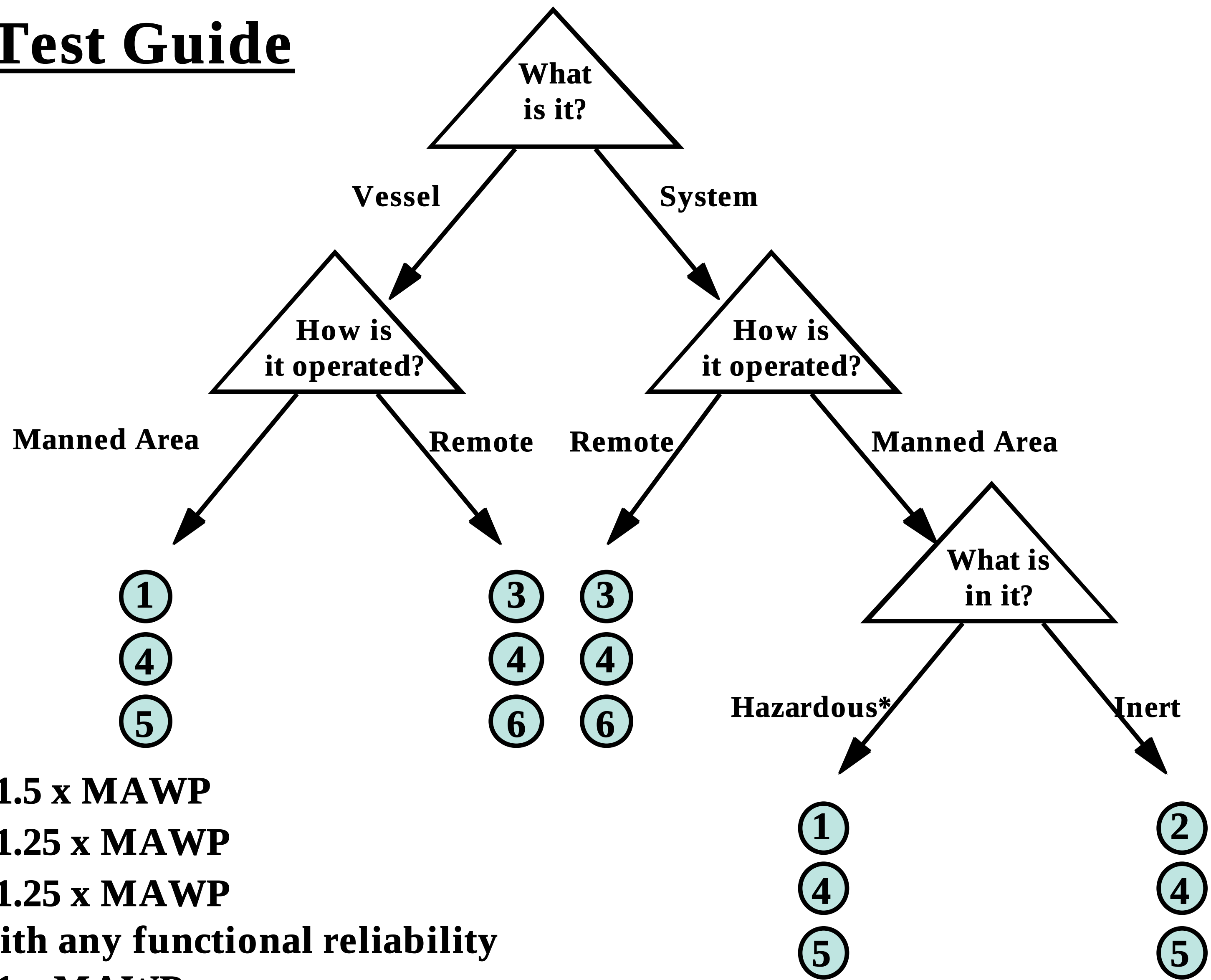
This documentation guide is intended for use at ambient temperature. Special consideration should be given to: strength of materials, reactive fluids, vibration, seismic safety, and/or operation at elevated temperatures.

Documentation Requirements

1. No ESN or OSP required (documented or hazards are low). Go to A
2. No ESN or OSP required, but notify PE facility operations. Go to A
3. Requires DOT approval or DOE - SAN exemption
4. No ESN required for the pressure equipment, but comply with DSS Ch. 4. An OSP may be required by H&SM Ch. 2.
5. ESN, PEL, and/or OSP required by H&SM Chs. 2 & 32 & by DSS Ch. 3.

LLNL Example

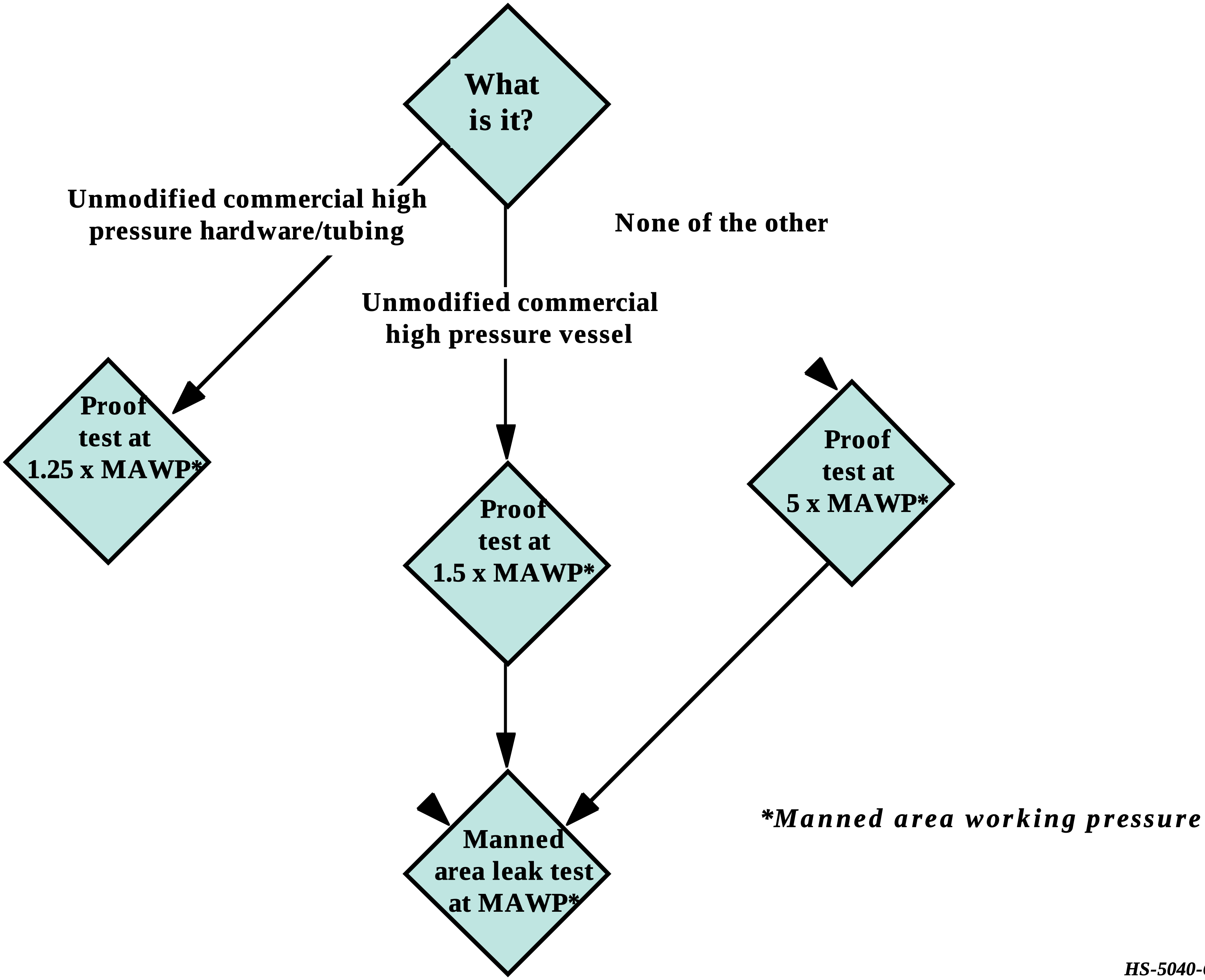
Leak/Proof Test Guide



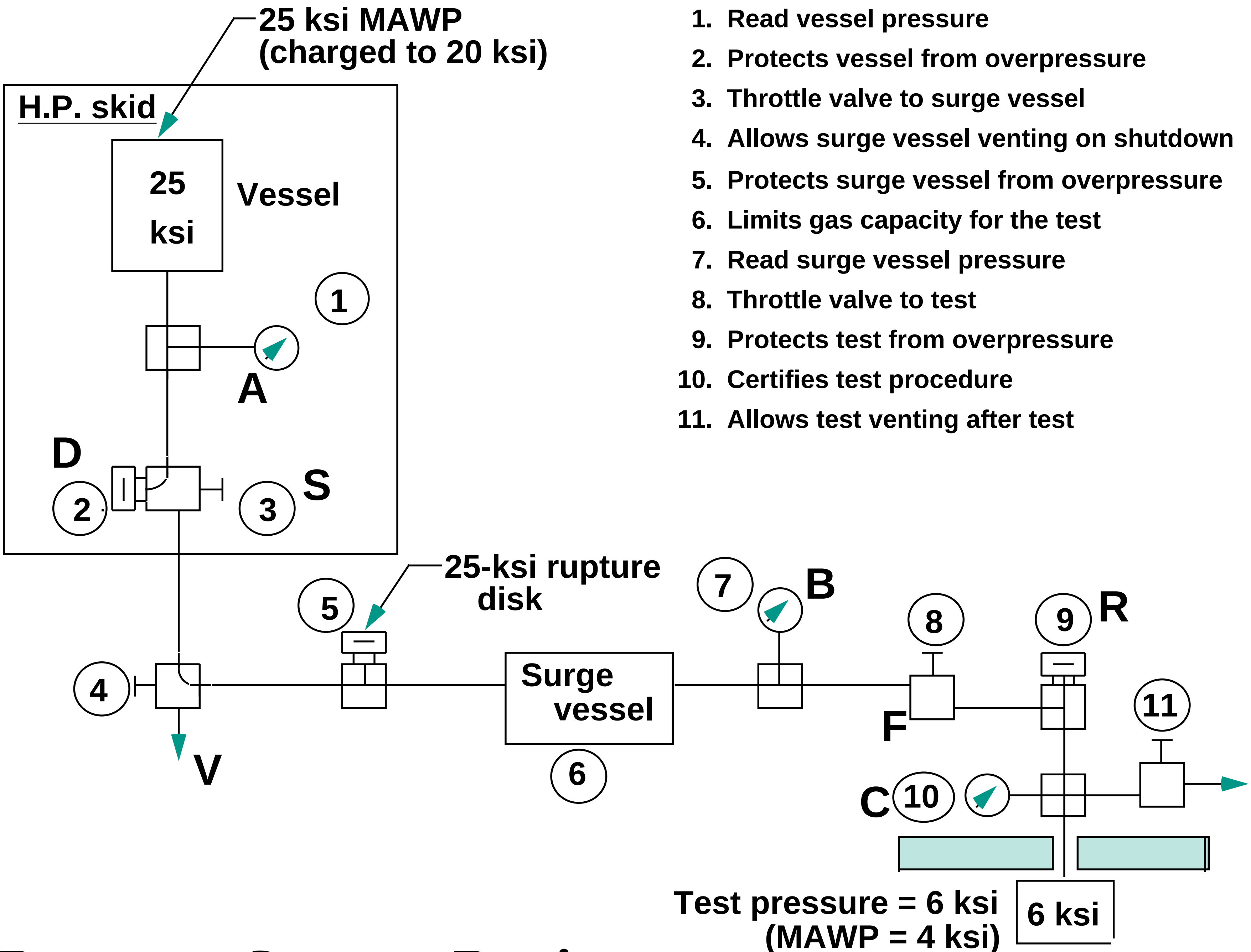
**Flammable*
Toxic
Radioactive

1 1st proof test - 1.5 x MAWP
2 1st proof test - 1.25 x MAWP
3 1st proof test - 1.25 x MAWP
or consistent with any functional reliability
4 Re-proof test - 1 x MAWP
5 Leak test - 1 x MAWP
6 Leak test - 0.2 x MAWP

Pressure Testing Guide

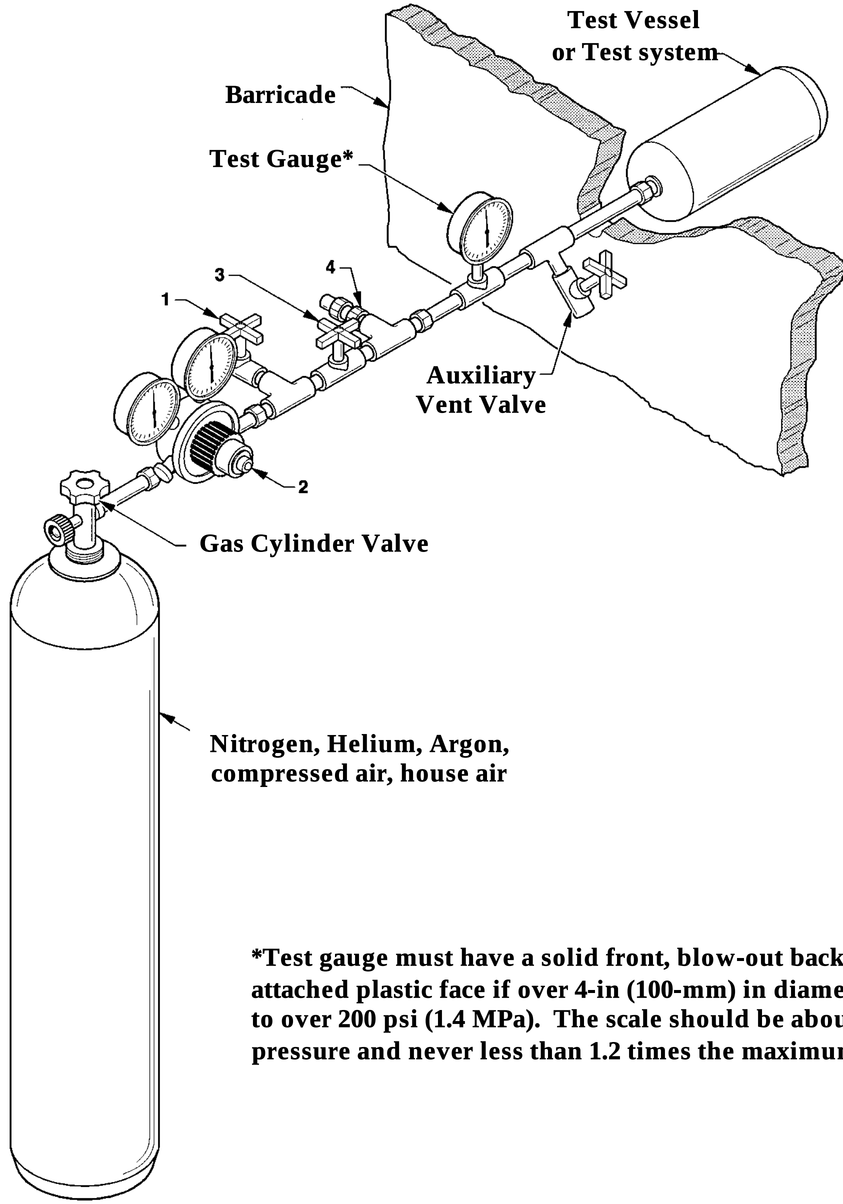


1. Read vessel pressure
2. Protects vessel from overpressure
3. Throttle valve to surge vessel
4. Allows surge vessel venting on shutdown
5. Protects surge vessel from overpressure
6. Limits gas capacity for the test
7. Read surge vessel pressure
8. Throttle valve to test
9. Protects test from overpressure
10. Certifies test procedure
11. Allows test venting after test



Pressure System Design

Setup for Pressure Testing with Gas



Legend

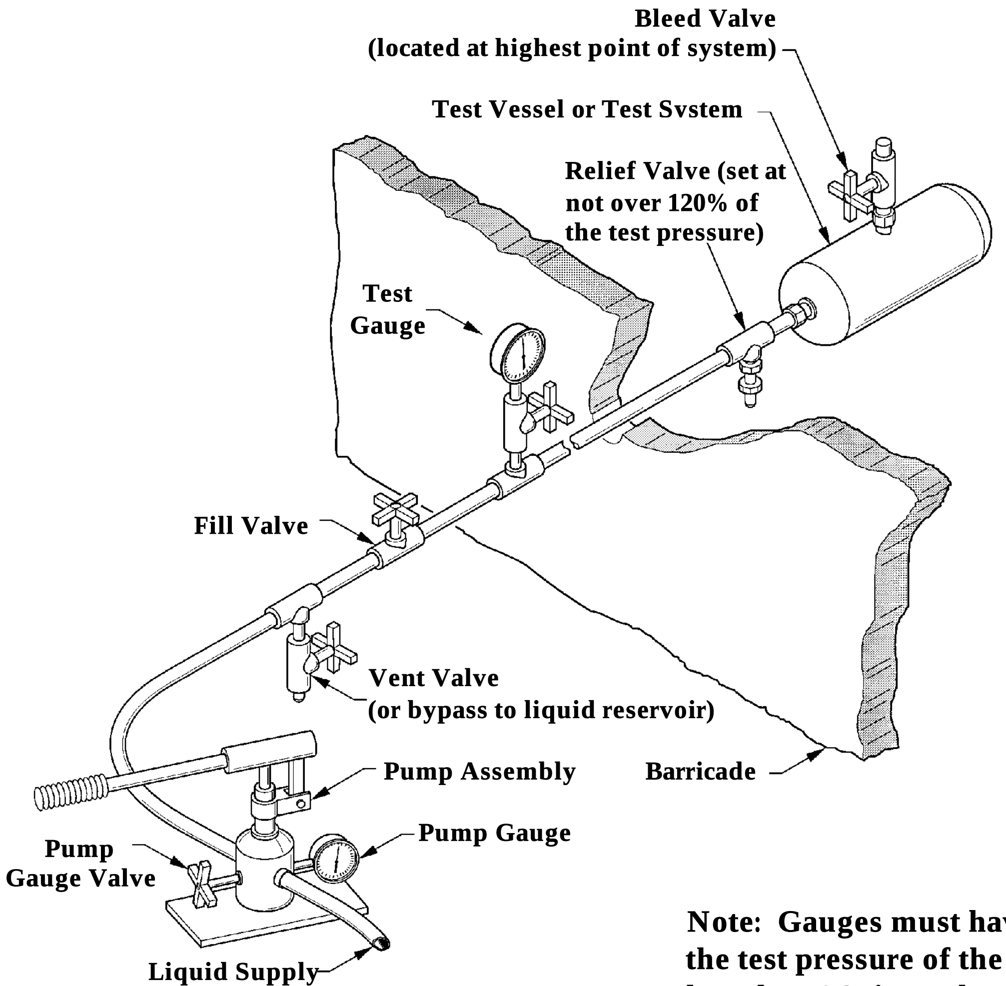
Safety manifold 3,000 psig (20 MPa) of MAWP:

1 Vent Valve
2 Regulator
3 Fill Valve
4 Relief Valve
(set at not over 120% of the test pressure)

***Test gauge must have a solid front, blow-out back, and securely attached plastic face if over 4-in (100-mm) in diameter and graduated to over 200 psi (1.4 MPa). The scale should be about double the test pressure and never less than 1.2 times the maximum test pressure.**

HS-5040-62

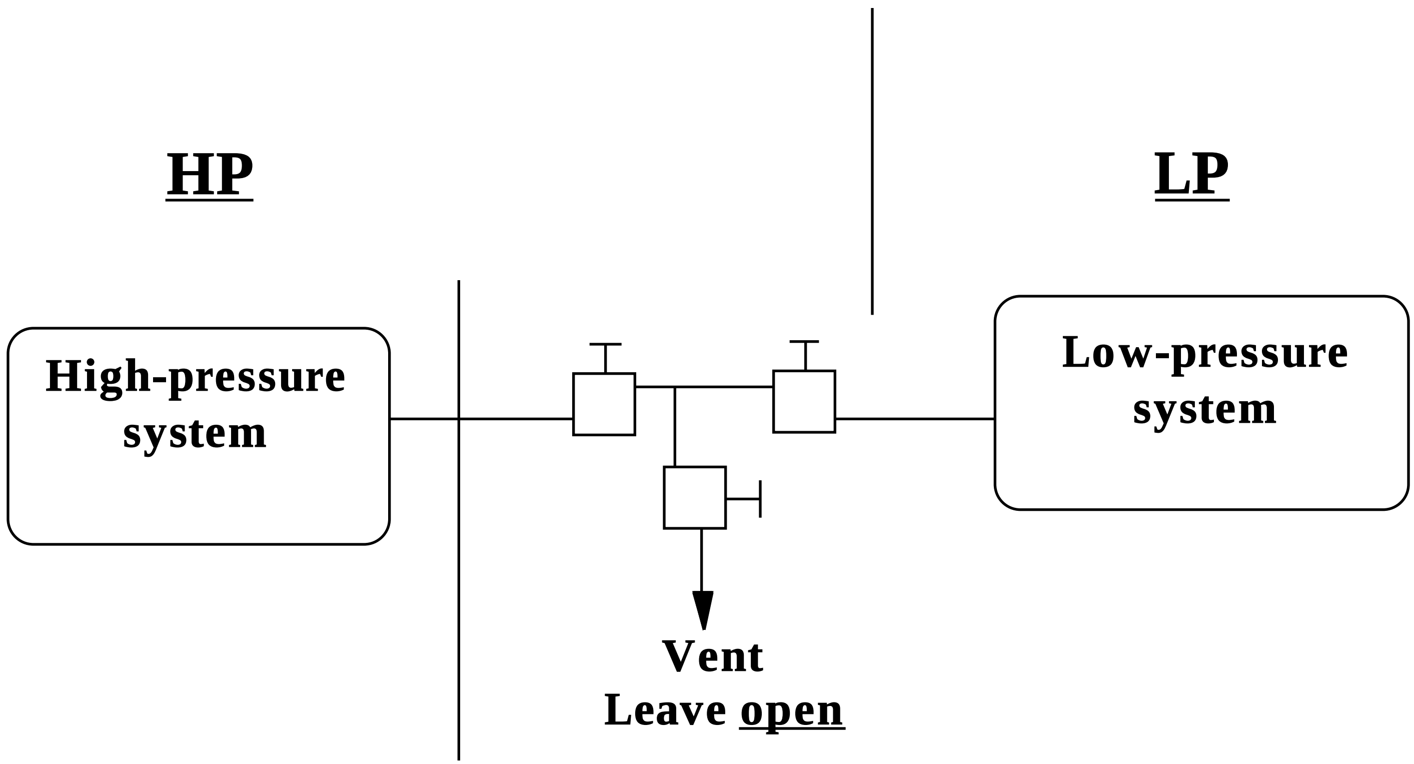
Test Setup for Hydrostatic Pressure Tests



Note: Gauges must have scales about double the test pressure of the tested vessel and never less than 1.2 times the test pressure.

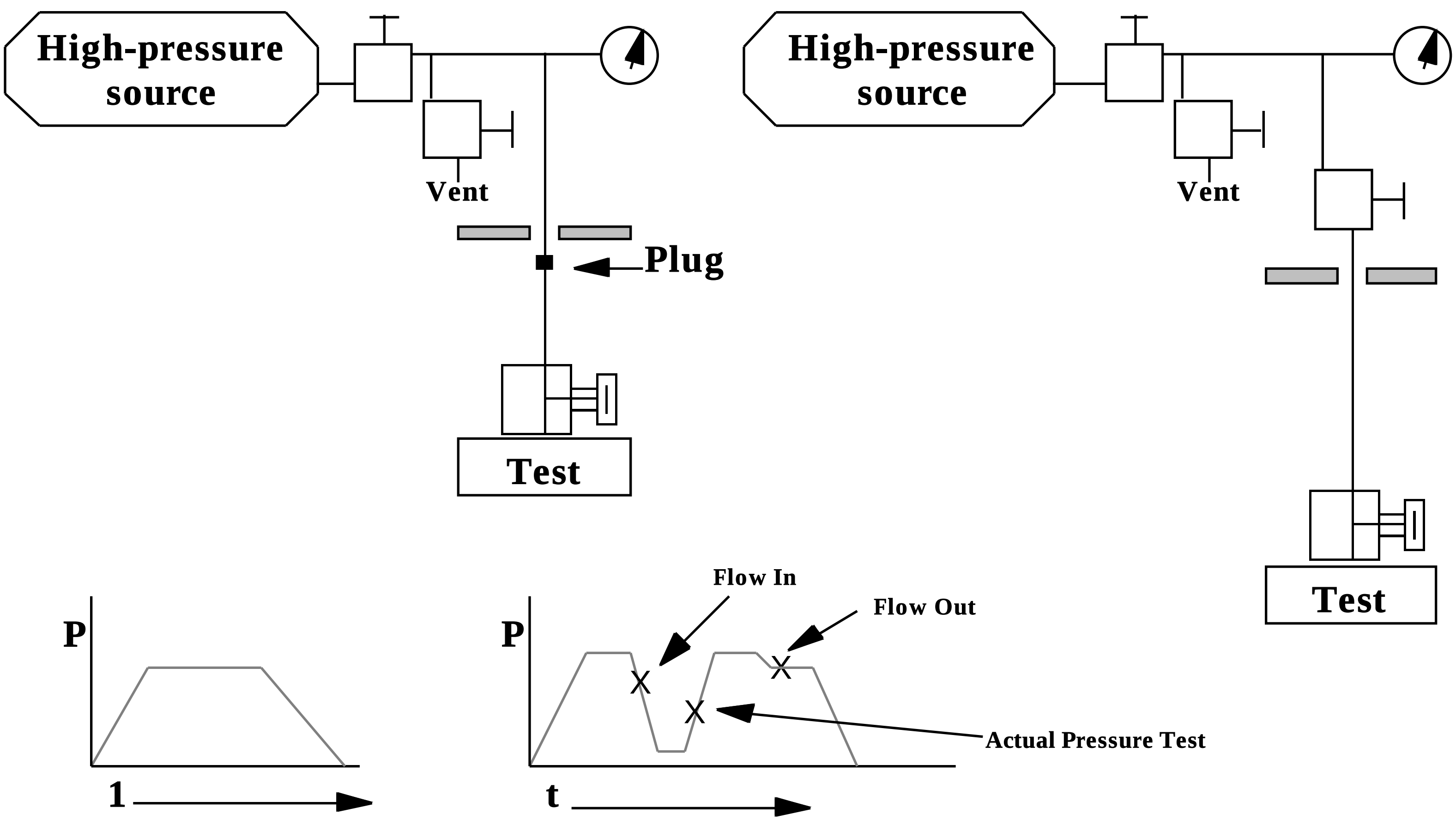
Worry About Valve Cross-Seat Leaks

❒ Provide a leak path for connected low-pressure sections.

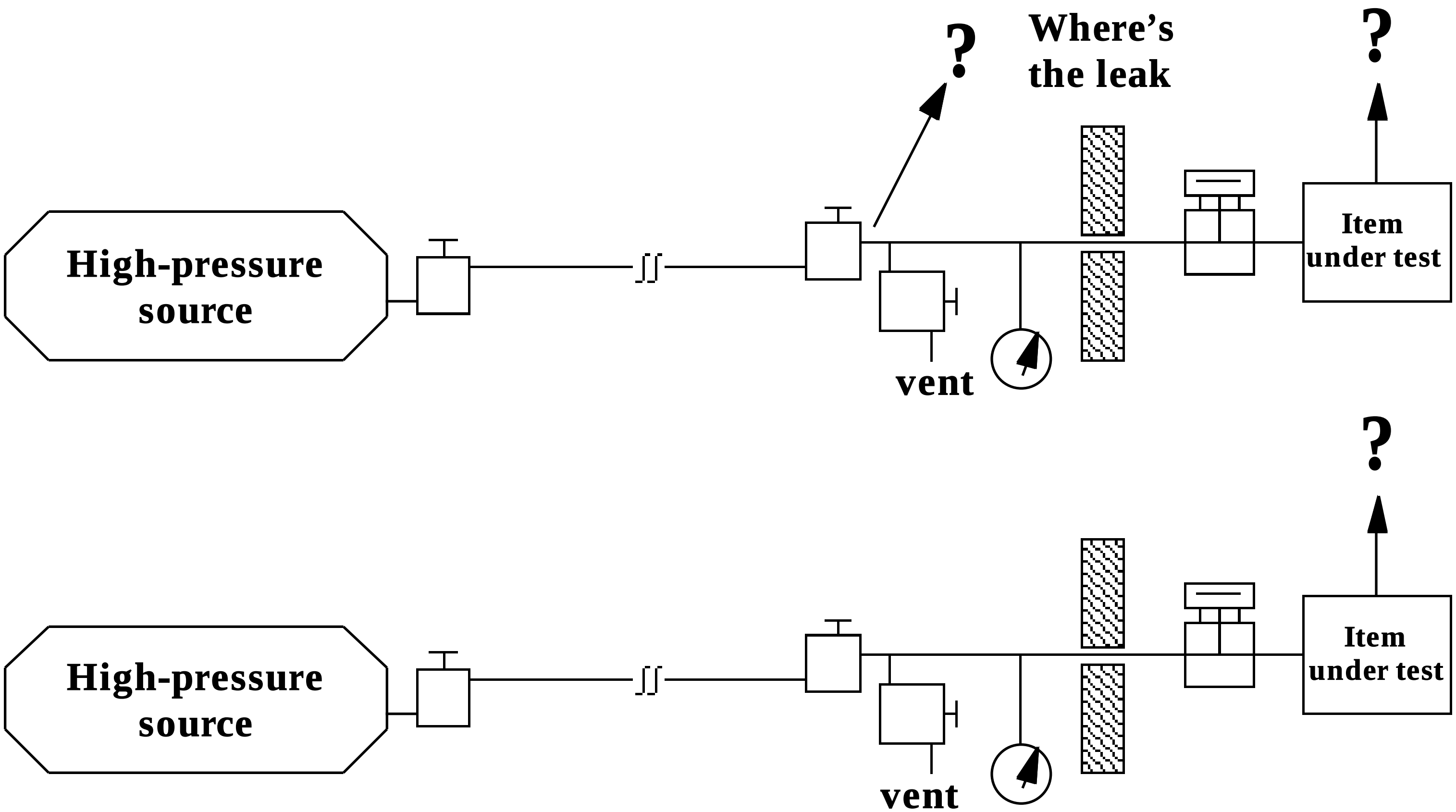


Did you test the part to the plumbing?

❒ **Always verify continuity – both directions**

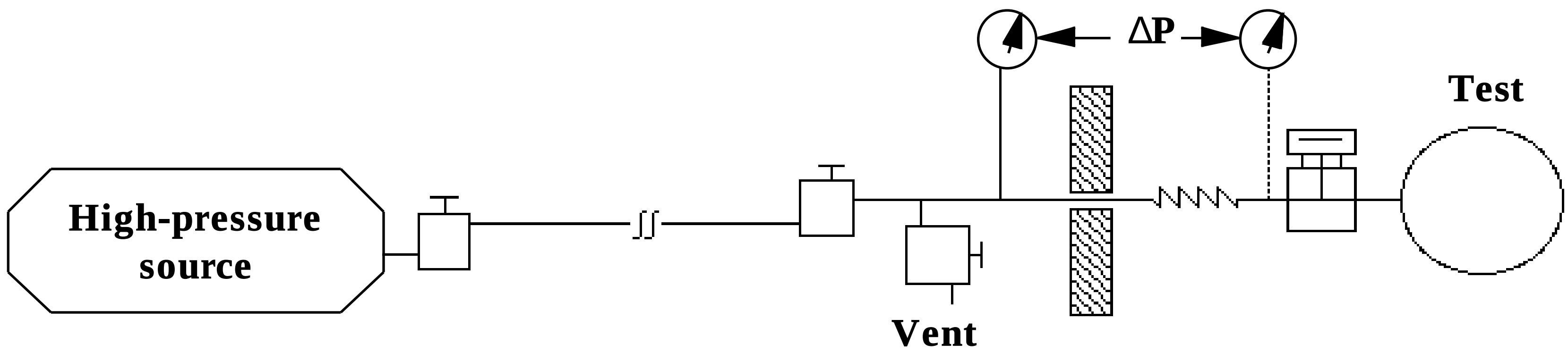


Pressurize the item, then close the valve

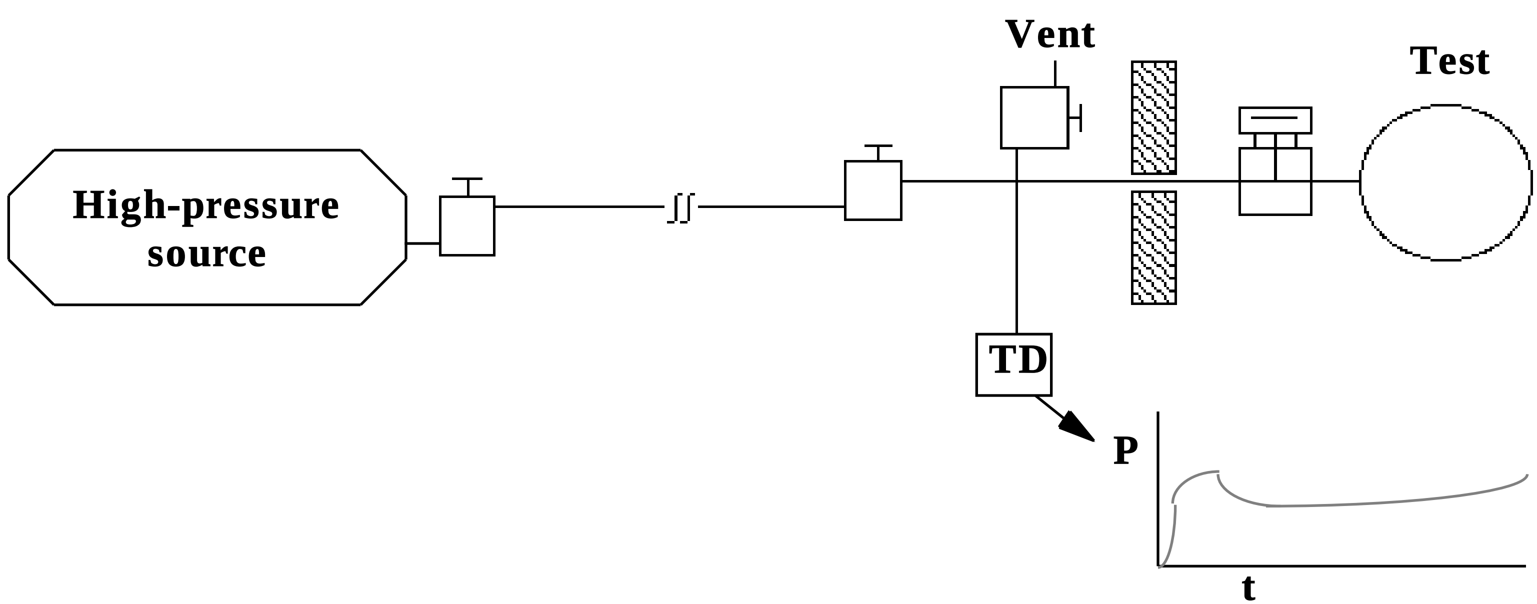


❒ **Position the final valve with packing away from the test.**

Consider pressure drop and compression heating effects

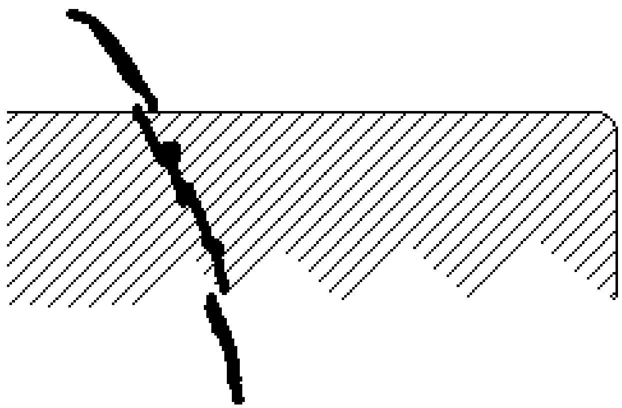


ΔP effect

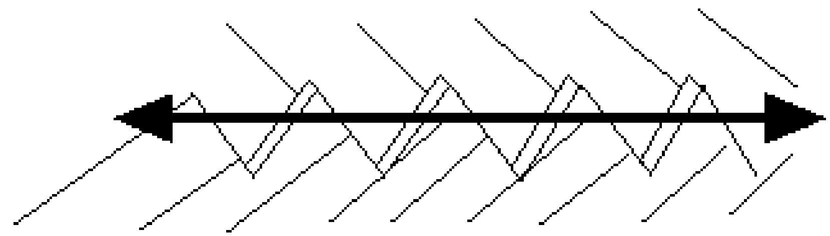


HS-5040-67

Do not tighten pressure fittings that are under pressure.



.....Don't even think about it!



Danger is overstress of an already stressed part . . . and failure.

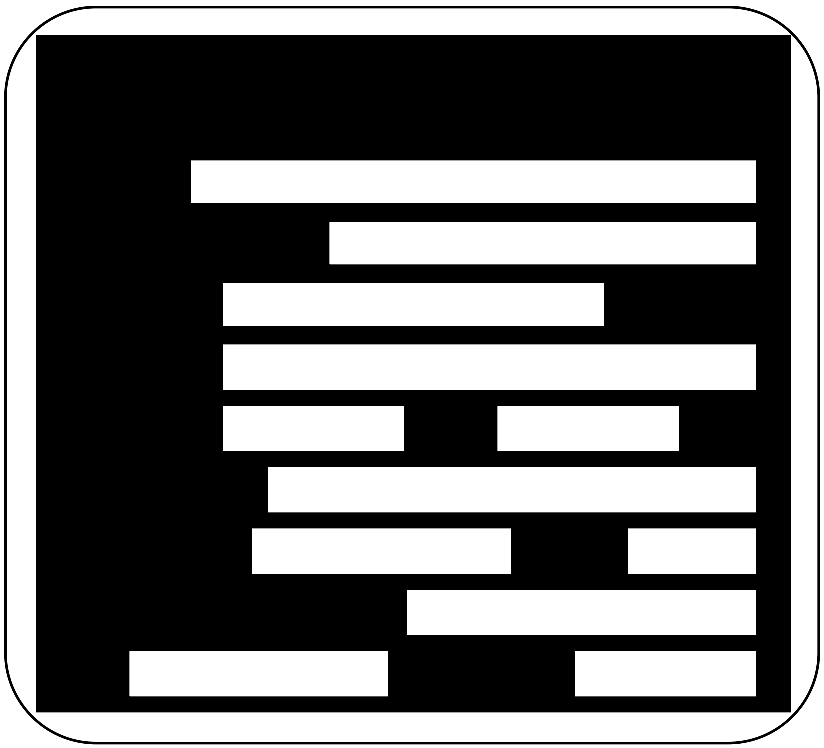
Leak testing is often required after pressure testing.

- Usually done at MAWP
- Best done as a manned area operation
- Simplest methods include:
  - Pressure drop on a gauge for a given time
  - Soap bubble indications
  - Under water bubble techniques

Most accurate method of leak detection employs a Helium mass spectrometer leak detector.

- **External sniffing of a Helium pressurized assembly using a leak detector probe . . . no quantity or rate.**
- **TIL (Total Integrated Leak) . . . bell jar-like measurement of total <u>quantitative</u> leak <u>rate</u>.**
- **Remote leak detection is also possible via bagging, test cell operation, etc.**

The concept of labeling pressure vessels and systems is drawn from the ASME code stamping system.



U

Certified by

(Name of Manufacturer)

psi at °F

(Max. allowable working pressure)

W (if arc or gas welded)
RT (if radio-graphed)
HT (if postweld heat treated)

(Manufacturer's serial number)

(Year built)

LLNL Example

HS-5040-71